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ART. XXXI.—*On the Duration of Color Impressions upon the Retina;* by EDWARD L. NICHOLS, Ph.D.

[Read at the Montreal meeting of the American Association for the Advancement of Science.]

IT is now more than half a century since the publication of Plateau's well known researches upon persistence of vision.* In his experiments the velocity was determined at which a revolving disk with alternate black and white sectors began to present a homogeneous surface to the eye; and this rate was taken as the measure of the duration of the image formed upon the retina by the bright parts of the disk. Upon substituting red, yellow and blue sectors for the white ones, Plateau found that the velocity necessary to this appearance of homogeneity was not always the same, being greatest when yellow was alternated with black upon the rotating disk, and least in the cases in which the white sectors were replaced by blue ones.

This discovery—that the duration of the impression made upon the retina by light depends upon the composition of the ray—became the basis of Plateau's theory of retinal after-images. It has found a partial confirmation in some experiments by Emdmann,† and has been very generally accepted by the writers on Physiological Optics; and yet after fifty years our knowledge of the manner in which the duration of the

* Dissertation sur quelques propriétés des impressions produits par la lumière sur l'organe de la vue. Liege, 1829.

† Emdmann, Poggendorff's Annalen, xci.

retinal image varies with the wave-length of the impinging ray remains in the condition in which Plateau left it. The results of his measurements are given in the following table:

Duration of color-impressions according to Plateau.

Color of the alternate sectors.	Total duration of the image.	Undimmed duration of the image.
White,	0·35 seconds.	0·00796 seconds.
Yellow,	0·35 "	0·00798 "
Red,	0·34 "	0·00966 "
Blue,	0·32 "	0·01229 "

The total duration of the image was determined from the slowest rotation which would entirely blur the black sectors of the revolving disk. The time during which the image remained undimmed was calculated from the velocity necessary to give the face of the disk a uniform tint.

Emdmann found the duration of the images to be:

White $=0{\cdot}25''$ Red $=0{\cdot}24''$
Yellow $=0{\cdot}27''$. Blue $=0{\cdot}22''$ to $0{\cdot}29''$

These values probably refer to the total duration. Helmholtz* found the undimmed duration of the image when the disk was illuminated by lamp-light to be $\frac{1}{48}$ of a second, by moon-light $\frac{1}{20}$ of a second.

Deeming this phenomenon worthy of further study, the writer has determined, by a modification of the method of Plateau, the persistence of the retinal image as a function of the wave-length of the ray producing it. The measure of the duration of the image, adopted in the experiments to be described, was the longest interval which could be allowed to occur between successive exposures of the retina without interfering with apparent continuity of vision. An ordinary one-prism spectroscope† was so placed as to give a fairly pure spectrum of a beam of diffuse white daylight, the Fraunhofer's lines being well defined. A black disk 240^{mm} in diameter, with four narrow open sectors 5^{mm} each in width, was rotated before

* Helmholtz, Handbuch der physiologischen Optik, p. 372.

† Professor Rood, in "Modern Chromatics," a treatise to which the writer owes much, has proposed the use of the spectroscope and revolving disk for the study of the duration of retinal images. He says (p. 206), "Dr. Wolcott Gibbs suggested to the author a method which would probably solve this problem in a satisfactory manner, and which is about as follows: With the aid of a spectroscope, a diffraction spectrum is to be presented to the eye in the form of a series of contiguous colored bands, this division into bands being effected by a suitable diaphragm placed in the eye-piece of the instrument. In front of the slit of the spectroscope, a revolving disk with one or more openings should allow the light to enter the instrument; and by carefully regulating the velocity of rotation it would be possible to seize the exact moment when one or more bands ceased to flicker and presented a steady uniform appearance. This observation would give correctly the interval during which the impression remained with undiminished strength on the eye, in the case of the selected color."

the slit of the spectroscope at the rate of two or three revolutions per second. The spectrum of the intermittent ray thus formed presented a very curious appearance. In the extreme red, one could observe but little change of luminosity as each black sector intercepted the light, but toward the center of the spectrum the perturbation became more and more marked, until in the region just beyond the D line there was simply a flash of light at the passage of each open sector, followed by an interval of darkness of noticeable length. Toward the violet the disturbance decreased again, until near the end of the visible spectrum the interruption could no longer be detected. This preliminary observation showed in a most striking manner how differently the various portions of the spectrum affect the eye. It only remained to determine the velocity of the disk at which each spectral region appeared entirely persistent and to calculate therefrom, as Plateau had done in the case of his parti-colored disks, the duration of the corresponding retinal image.

The portions of the spectrum chosen for comparison were situated as follows:

Spectral region.	Wave-length in ten-millionths of a millimeter.
Red	7420
Orange	6463
Yellow	6025
Green	5415
Blue	4784
Violet	4382

A diaphragm in the eye-piece of the spectroscope enabled the observer to exclude, during the course of each experiment, all parts of the spectrum not under observation.

It was found by experience that the lowest velocity producing continuity of vision could be best determined by taking advantage of the following phenomenon. The transition from a broken to a persistent retinal image is marked by the appearance of a peculiar blur or shadow in the center of the field of view. At a certain velocity of the disk, just as the image begins to lose its definitely intermittent character, this shadow always appears; fading at a slightly higher rate of rotation to give place to a field of unbroken illumination. The velocity corresponding to its disappearance was accordingly adopted as the best measure of the duration of the image formed by the light from the different parts of the spectrum. The first attempt to carry out the comparison of the images produced by different wave-lengths showed that the time to be measured, "the time of apparent constancy" as Plateau terms it, fluctuated through a very wide range, changing with the intensity of

the light and with the condition of the observer's eye. The variations due to the change of sensitiveness of the eye were so marked and so rapid that any attempt to compare different portions of an extended series of measurements had to be abandoned. The increased accuracy to be derived from a large number of readings was more than overbalanced by the errors due to variations in the condition of the retina. By running rapidly through the spectrum, taking a single measurement in each region, it was found possible to obtain series of readings during the course of which the eye had not appreciably varied.

The method of observation was very simple. The axle upon which the disk revolved was connected by an endless band with a fly wheel of weight sufficient to insure the necessary uniformity of motion. This fly wheel was turned by the observer, who increased its speed, watching the spectral region under inspection, until the appearance of the above mentioned shadow indicated the transition from interrupted to continuous vision. The motion was then kept as nearly uniform as possible for one minute, during which an assistant counted the revolutions of the disk. The observer, by watching the field of view mean time, could detect slight changes in velocity.

The following tables give some of the results obtained by this method. The wave-lengths are those of the middle of each spectral region. Although the brightness of the spectrum and the sensitiveness of the observer's eye were not the same in the different series, they did not vary appreciably, so far as known, between the beginning and end of any single series.

Series A.

Spectral region.	Revolutions per minute.	Interval between exposures of retina.	Duration of exposure.
7420 (red)	136	0·1074 seconds.	0·00293 seconds.
6463 (orange)	150	0·0961 "	0·00266 "
6025 (yellow)	171	0·0850 "	0·00232 "
5415 (green)	140	0·1044 "	0·00285 "
4784 (blue)	130	0·1125 "	0·00306 "
4382 (violet)	88	0·1662 "	0·00452 "

Series B.

[Spectrum brighter than in Series A.]

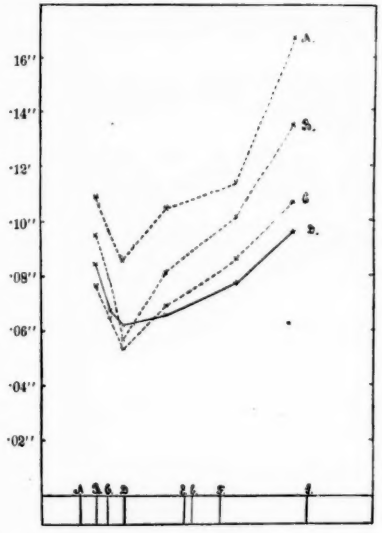
Spectral region.	Revolutions per minute.	Interval between exposures of retina.	Duration of exposure.
7420 (red)	154	0·0949 seconds.	0·00259 seconds.
6463 (orange)	186	0·0786 "	0·00214 "
6025 (yellow)	260	0·0562 "	0·00153 "
5415 (green)	180	0·0812 "	0.00221 "
4784 (blue)	144	0·1015 "	0·00277 "
4382 (violet)	108	0·1355 "	0·00369 "

Series C.

[Spectrum brighter than in Series B.]

Spectral region.	Revolutions per minute.	Interval between expcsures of retina.	Duration of exposure.
7420 (red)	190	0·0769 seconds.	0·00209 seconds.
6463 (orange)	228	0·0641 "	0·00175 "
6025 (yellow)	280	0·0523 "	0·00144 "
5415 (green)	212	0·0690 "	0·00188 "
4784 (blue)	170	0·0860 "	0·00234 "
4382 (violet)	136	0·1072 "	0·00286 "

Inspection of these three tables and of the accompanying curves shows that the image formed by yellow light is less persistent than that produced by any other color, and that the



duration of the image increases rapidly as we approach either end of the spectrum. Aside from the inaccuracies, inevitable in the comparison of single observations of this nature, the three curves representing series A, B, and C, are of the same general character. The minimum of duration is in the same region in each curve. It will be seen that the duration of the image is least in the series corresponding to the brightest spectrum and greatest with the darkest spectrum; and that changes in brightness affect the persistence of the images formed by the different spectral regions in nearly the same proportion.

The law of the dependence of the duration of color-impressions upon the intensity of the ray could doubtless be determined by

repeating these measurements with spectra of known and varied brightness. The writer indeed made a series of preliminary measurements with this end in view. The spectrum of a gas flame was substituted for that of daylight and its brightness varied by the method of Vierordt, i. e. by changing the width of the slit. At the low intensities thus obtained the fluctuations in the sensitiveness of the eye were so great as to defeat the object in view. The observations only served to confirm the fact already established, that with diminishing brightness of the spectrum the image increases in duration.

By comparing the curves A, B, and C with that indicating the relative luminosity of different parts of the solar spectrum, as measured by Fraunhofer and independently by Vierordt, we find that the maximum of luminosity corresponds in position with the minimum of duration of the retinal image. The variations in luminosity of the different parts of the spectrum* are far greater than the changes in the duration of the color-impressions produced by the corresponding wave-lengths, but the two are not directly comparable because the luminosity was determined for a vastly brighter spectrum. The effective brightness of the spectrum for which the persistence of the retinal image was measured, was, according to Talbot's law for the luminosity of rotating black and white disks, only $\frac{5}{183}$ as great as that of the spectrum of uninterrupted daylight, seen through the same instrument. The difference is about that between the intensity of light reflected by white paper, on the one hand, and from a lamp-blacked surface on the other. Since the relative sensitiveness of the eye for different wave-lengths varies with the intensity of the ray, being proportionately much greater for the more refrangible rays when the intensity is small, the luminosity curve of a faint spectrum

* The relative luminosity of different portions of the spectrum as determined by Fraunhofer and Vierordt are given in the following table. Their results are of interest in this connection because of the relation between the luminosity and the duration of the corresponding impression upon the retina, and because they show that the luminosity differs for different eyes in much the same way as the duration of the image is found to do.

Luminosity of the Spectrum.

Fraunhofer.[1]		Vierordt.[2]	
Red (B)	32	Red (B)	22
Orange (C)	94	Orange (C)	128
Yellow (D)	640	Yellow (D)	780
Yellow (D to E)	1000	Yellow (D to E)	1000
Green (E)	480	Green (E)	370
Blue-green (F)	170	Blue-green (F)	128
Blue (G)	31	Blue (G)	8
Violet (H)	5·6	Violet (H)	0·7

[1] Denkschrift der Bayerischen Akademie, 1815.
[2] Anwendung der Spectral-Analyse, Tübingen, 1871.

would be much flattened, at any rate toward the violet, and its values would be more nearly in inverse proportion to the duration of the retinal images, in series A, B, and C.

To determine whether the general form of the curve for the duration of color-impressions was the same for all eyes, Mr. Wilson Sterne, of Texas, who had been assisting the writer in the measurements already described, made the following set of readings. The conditions were the same as those under which series B had been obtained. As may be seen from the following table and from the corresponding curve (D), the variations in the duration of the image upon Mr. Sterne's retina are very different from those represented in series A, B, and C. The impression of yellow lasts longer, while the green and blue images fade more rapidly. These measurements were repeated many times, the curve always taking the general form shown in curve D.

Series D.

Conditions, those of Series B; Wilson Sterne observing.

Spectral region.	Revolutions per minute.	Interval between exposures of retina.	Duration of exposure.
7420 (red)	176	0·0831 seconds.	0·00226 seconds.
6463 (orange)	214	0·0683 "	0·00186 "
6025 (yellow)	238	0·0614 "	0·00167 "
5415 (green)	224	0·0653 "	0·00178 "
4784 (blue)	190	0·0770 "	0·00210 "
4382 (violet)	148	0·0988 "	0·00270 "

It seems very probable that no two observers would obtain the same curve, but our present knowledge of physiological optics is not sufficient to enable us to point out the true cause of the variation. Perhaps unusual sensitiveness of the eye to certain portions of the spectrum may lessen the duration of the corresponding color-impressions, just as the increased brightness of the ray itself is known to do. If this be true, the phenomenon stands closely related to color-blindness; the precise nature of the relation can only be determined by comparing the sensitiveness of individual eyes to different spectral tints with the duration of the image produced by the same colors.

A minor phenomenon observed during the course of these experiments seems to show that the duration of color-impressions does not depend, fundamentally, upon the wave-length of the ray producing them; but that it depends, like color itself, wholly upon the character of the nerves affected. When the entire spectrum of the intermittent ray was observed, with the disk in very slow rotation, so slow as to cause flickering even in the violet, the image of the yellow and green portions disappeared first, leaving behind it a dark violet band extending the

whole length of the spectrum. By regulating the speed of the disk, this band could be maintained in a nearly quiescent state while the dominant color of each wave-length appeared and disappeared with the passage of each open sector. This phenomenon can be readily explained in the terms of the Young-Helmholtz theory of color, of the truth of which it affords at the same time new evidence. Each wave-length produces three separate impressions upon the retina, the sensation of red upon nerves intended for the transmission of that sensation, the sensation of green, and that of violet, upon nerves adapted to carry those impressions to the brain. These three impressions are blended in a resultant color-sensation, the nature of which depends upon the relative intensities of the components. Upon the wave-length of the impinging rays it depends only in so far as these have a greater or less power of affecting one or the other of the three sets of nerves. The effect of stimulating a "red," "green" or "violet" nerve, is always the sensation we call red, green, or violet, as the case may be, no matter what the nature of the stimulating agent, and *the varying duration of color-impressions is due primarily to variations in the rapidity with which these nerves recover from the action of the impinging ray.* Of the three primary sensations, green is the most transient and violet the most persistent. Upon this supposition it is easy to see that whatever may be the predominant tint of a ray of light under ordinary circumstances, the final impression, after the ray has ceased to act, will be one of violet.

This observation upon the spectrum of an intermittent ray is closely allied to a variety of well known experiments, in which color-impressions are produced by the slow movement of white objects upon a black ground. Aside from the dying away of one component of the image after another we have to take into account the varying rapidity with which different color-images reach their maximum intensity. To this latter cause von Helmholtz* and others ascribe the production of "subjective" colors in these cases. Taken in conjunction, the two causes are capable of producing a great variety of "subjective" tints. Those produced by the more rapid disappearance of the yellow and green portions of the image are similar to the colors which white assumes to green-blind persons, the depth of color depending upon the rate of rotation of the disk. As the disappearance of these components is followed by that of the red portions of the image, the effect will be that of partial red-blindness combined with green-blindness. Under varying velocity a white surface would successively become pink, rose-colored, purple and violet.

The duration of color-impressions varies also with the length

* Von Helmholtz: Handbuch der physiologischen Optik, p. 380.

of time the retina has been exposed. Plateau, in the paper already cited, gives a curious law for the velocities necessary to produce apparent uniformity of surface upon black and white disks. He found that any two disks composed of alternate black and white sectors will attain a uniform tint at the same velocity, provided the black sectors in the one are equal in width to each other and to the white sectors in the other disk. That is to say, a black disk with narrow white sectors presents a homogeneous surface at the same velocity as does a white disk with the same number of similiar narrow black sectors; and this holds true, no matter what the number and width of the sectors may be. In a more recent paper, Plateau gives some measurements of the rate of rotation of such disks. The law was not put to a test in his experiments, as it might have been, since the disks for which measurements were made were black, with white sectors never exceeding the black ones in width.

The present writer, to determine the manner in which the duration of the retinal image varies with the length of exposure, made use of black disks with two diametrically opposed, open sectors, the latter varying in width from 45° to 176¾°. Through the open sectors of these revolving disks the intermittent spectrum of a gas flame was observed, and, as in the experiments already described, the velocity of rotation was increased until the yellow portion of the spectrum ceased to flicker. From the velocity of the disk and width of the black and of the open sectors, was calculated the duration of the image formed during various exposures. The following table shows the results:

Exposure of retina,	Duration of the image,
0·0124 seconds.	0·0954 seconds.
0·0274 "	0·0824 "
0.0717 "	0·0717 "
0·1314 "	0·0654 "
0·2316 "	0·0463 "
0·4506 "	0·0409 "
0·7566 "	0·0327 "

These values are not in accordance with Plateau's law. The series, unfortunately incomplete, indicates that upon increasing the time during which the retina is exposed, the duration of the image approaches a finite minimum, (probably about 0·02″ for the intensity in question). By decreasing the exposure, however, the duration of the image would seem to become indefinitely extended. Plateau's law carried to the limit requires the duration of the image to become indefinitely long for an infinitesimal exposure, and to become zero for an exposure equal to a single revolution of the disk. We know by the study of after-images that their duration after short exposures of the

retina may be very long, but that a long exposure should be followed by no after-images seems contrary to common experience.

The results of the experiments described in this paper may be briefly summed up as follows.

1. The study of the duration of color-impressions produced by different portions of the spectrum, confirms, in the main, the results reached by Plateau.

2. The persistence of the retinal image is a function of the wave-length producing it, being greatest at the ends of the spectrum and least in the yellow.

3. It decreases as the intensity of the ray producing the image increases.

4. The relative duration of the impressions produced by the different spectral colors, is not the same for all eyes.

5. The duration of the retinal image is in inverse order to the luminosity of the colors producing it.

6. Each wave-length of the visible spectrum produces three primary impressions, red, green and violet; of which green disappears most rapidly and violet is the most persistent. Upon the different rates at which these impressions die away depend to a great extent the "subjective" tints of moving objects.

7. The duration of the retinal image depends upon the length of time during which the eye has been exposed, being very long after short exposures and approaching a definite finite minimum value as the exposure increases.

University of Kansas, June, 1884.

Art. XXXII.—*Fulgurite from Mount Thielson, Oregon;* by J. S. Diller.

The occurrence of lightning-tubes (Blitzröhren) or fulgurites, as they are frequently named, in this country has received little attention and it is very rarely that specimens have found their way into our museums. This cannot be due to their scarcity for there is good reason to believe they are common in the western part of the United States. They deserve special attention because they are the product of an exceptional method of fusion.

The terms fulgurite and lightning-tube are frequently used synonymously; but it seems desirable that the former be applied to the substance resulting from the electric fusion and the latter to the tubular form in which fulgurite usually occurs.

Mr. L. C. Johnson has just called my attention to some lightning-tubes found by Mr. Silas Stearns on Santa Rosa Island south of Pensacola, Fla. Mr. Stearns reports that where the tubular fragments were found there was a crooked trail of them lead-

ing from a tree struck by lightning, so that in this case, as well as in the one noted many years ago (1790) by Priestly, their electric origin is clearly indicated. Each of the two fragments is about 50 centimeters long, and the diameter of the tube varies from 7 to 15 millimeters. The smaller one retains its cylindrical character, but the other while in a plastic condition was collapsed by the pressure of the surrounding sand. Notwithstanding the fact that the walls of the tubes are only about 0·25^{mm} in thickness they are not fragile. They are pierced by numerous small openings, with fused edges, which help to make the surface very rough and irregular. Upon the outside the tubes are dull, but within they have a brilliant lustrous glazing. The fulgurite is translucent, of a light gray, almost white color, and contains many gas cavities. Under the microscope it appears for the most part perfectly clear and amorphous. There is rarely seen a light brown clouding, due to the presence of oxide of iron in the sand from which the fulgurite was produced by the electric fusion. Remnants of quartz grains may be discovered in the colorless glass, but they are not abundant.

Last summer a party of the U. S. Geological Survey, in my charge under the direction of Capt. Dutton, while making a reconnoissance of the Cascade Range, ascended Mt. Thielson, which is the most acute and precipitous peak south of the Columbia. It is the majestic remnant of a large deep crater to the southeastward. Ensign E. E. Hayden, who alone ascended the upper portion of the peak, reports that the last two hundred feet are very dangerous, the summit being small and the footing insecure.* Among the specimens collected upon the summit are several of fulgurite, that had been formed by the fusion of an interesting basalt, in which instead of augite, there is a rhombic pyroxene associated with the olivine. Chemical analysis has shown that the rhombic pyroxene is hypersthene. This basalt holds the same relation to hypersthene-andesite as ordinary basalt does to augite-andesite, and it may be designated *hypersthene-basalt.*

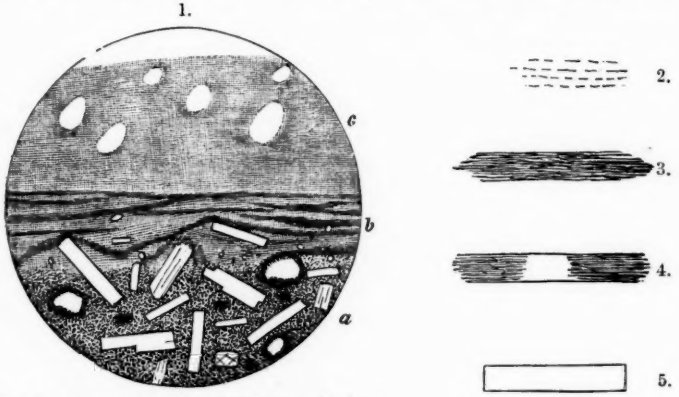
Although fulgurite is frequently formed by the fusion of loose sand it is seldom seen in connection with solid rocks. Saussure found the hornblende schist on the summit of Mont Blanc coated with drops and bubbles of blackish glass which were attributed to lightning. A yellowish enamel formed by the fusion of mica schist was observed by Ramond on one of the prominent summits of the Pyrenees. In the same region he found a similar effect produced upon fragments of siliceous fetid limestone. In all of these cases the fulgurite occurs as a

* Since this article was written the author has ascended Mt. Shasta, Cal., and found upon its summit fulgurite in the form of incrustations and lightning-tubes.

purely superficial coating, and not in the form of lightning-tubes. It has also been observed in connection with phonolite (?) (Klingstein porphyr) in the Auvergne; and Humboldt found it on one of the very acute volcanic mountains of Mexico, where it had resulted from the fusion of "reddish trachytic porphry" (andesite?). The summit, like that of Mt. Thielson, is very small and precipitous, and the vesicular, spongy rock furnishes insecure footing. Here lightning-tubes were found penetrating the porous mass, and in several cases it seemed as if the fulgurite, welling up out of the tube, had overflowed the adjoining surface. The most interesting and extensive development of fulgurite, however, has been pointed out by Abich as occurring upon Little Ararat, in Armenia, where the whole summit of augite-andesite is perforated by numerous lightning-tubes to considerable depths. Wichmann examined the fulgurite microscopically and found it a pale green glass full of gas pores.

The fulgurite of Mt. Thielson occurs in the form of a superficial coating and lightning-tubes. Although spread over a considerable surface, it is not evenly distributed, but is arranged in patches of drops and bubbles of glass in very much the same way as paint which has been put upon a greasy surface. The drops and bubbles of glass are translucent and have a greenish brown color. Many of them have conical depressions which appear to have been produced by atmospheric pressure while the fulgurite was in a viscous state. The thickness of the coating between the bubbles is about $0{\cdot}2^{mm}$, and lighter colored. At several places where lightning-tubes descend from the surface into the rock the fulgurite has accumulated around the hole. The rock is porous and at places even spongy. The cavities are lined with minute clear colorless crystals and it appears evident that this structure has not been produced by the electricity. Lightning-tubes, ranging in diameter from $10{\cdot}5$ to 20^{mm}, penetrate the rock a few inches. They appear to have been formed by lining preëxisting tubes and cavities with fulgurite; for there is no evidence of compression in the adjoining rock. The fulgurite walls of one of these tubes has a thickness of 2^{mm}; it is filled with round bubbles so as to be almost pumiceous and its interior is brightly glazed. The hardness of the fulgurite is a little below that of ordinary glass. It is rather tough, strongly lustrous, and has a specific gravity of about $2{\cdot}5$. In the flame of an alcohol lamp thin splinters readily fuse without intumescence. The groundmass of the rock fuses much less readily than the fulgurite to a very dark glass. Small fragments of the fulgurite when heated become strongly magnetic. It appears to be entirely insoluble in strong acids, even in aqua-regia, and is not affected by boiling solutions of potassium

hydrate or sodium carbonate. The accompanying figure (fig. 1) represents a section of one side of a lightning-tube and shows the relation of the fulgurite to the unaltered basaltic rock which appears beneath. Its line of contact with the fulgurite is irregular. The black-bordered olivine grains and crystals of feldspar project into it and show no prominent effects of the fusion, while the hypersthene is distinctly rounded on the edges and the groundmass has been melted much more readily than any other portion of the rock. The fulgurite is divided into two more or less distinct bands. The band (*c*) nearest the middle of the lightning-tube is a uniformly light coffee-brown glass, which



Section of one side of a Lightning-tube from Mt. Thielson, Oregon. *a*, unaltered hypersthene basalt; *b*, mixed zone; *c*, fulgurite.

contains a number of nearly spherical vesicles. Between the zone of pure fulgurite (*c*) and the unaltered rock (*a*) there is a narrower belt (*b*) in which the fusion has been less complete and the dark fluidal banding parallel to the length of the tube is prominent. This zone is frequently more or less granular. It is not only penetrated by crystals of feldspar, hypersthene and olivine projecting from the adjacent rock, but envelops numerous crystal remnants of these minerals scattered throughout. It contains some small round bubbles, but they do not appear nearly so abundant as in the fulgurite described by Wichmann from Little Ararat; nor have I been able to discover any radial arrangement in the longer axes of the larger vesicles. The superficial coating of fulgurite is composed wholly of coffee-brown glass without any marked fluidal structure.

A striking feature of the fulgurite is the absence of all products of crystallization from the electric fusion. It is true that fulgurite frequently envelops crystals and crystal fragments,

but these are easily recognized as remnants of that portion of the rock melted to produce the fulgurite. They are not the products of crystallization from the electric fusion but from previous volcanic fusion. The entire absence of all crystallites and all microlites which are usually abundant in tachylyte, hyalomelane and obsidian may be used as a means of distinguishing fulgurite from other natural glasses. It is doubtless due to the fact that the source of the heat being very limited in both time and space, the cooling is so sudden that there is no opportunity given for the crystallizing forces to act before the mass is rigid. That the cooling takes place very suddenly is shown by the lightning tubes in loose sand where, by the electric current, the sand is thrust aside, a hole made, the sand fused, and the tube formed and cooled in many cases before the sand can rush together again to fill up the hole. In some cases, however, the pressure of the sand is so great that the tube while soft is collapsed without breaking. That the fulgurite was cooled very suddenly is shown also by the fact that when heated red hot for but two minutes in a Bunsen flame and then examined under the microscope the beginnings of crystallites can be readily detected. As already stated, the microscope revealed the fact that the fulgurite was formed chiefly by the fusion of the groundmass.

In order to determine more fully the character of the material melted, an attempt was made to crystallize the fulgurite. A completely amorphous fragment nearly as large as a pea was kept at a red heat in a Bunsen flame for six hours. It fused very slightly on the exterior and lost its vitreous character entirely. A thin section of it under the microscope showed that it had assumed a distinctly, radial-fibrous, microfelsitic structure. A larger portion of fulgurite was taken, finely pulverized and fused in a small platinum crucible before a blast lamp for nearly five hours without intermission. When cooled the fused mass in the lower part of the crucible was found to be clear and colorless, while the upper portion was tough, black and basaltic in appearance. Under the microscope the dark colored portion was found to be crowded with distinctly striated feldspar microlites and a multitude of others, very minute, which were indeterminable, besides many minute octahedrons of magnetite. Between these microlites, arranged in a basaltic fashion, could be detected a trace of pyroxene, apparently monoclinic, with considerable brownish glass and dark globulitic base. An interesting feature in this section is the accumulation of the smallest microlites into elongated groups (fig. 2) in which all the individuals are parallel, as if to indicate their ultimate combination to form a single crystal. The clear and colorless portion of the fused mass found upon the bottom of the crucible con-

tained many perfect crystals of feldspar and shows very completely their development from bundles of microlitic fibers. The fibrous bundles (fig. 3) frequently have irregular ends, but the sides are generally straight. Consolidation begins in the middle, as represented in figure 4, and gradually advances both ways, until a perfectly clear compact crystal of feldspar (fig. 5), without any trace of fibrous structure, is completed. The elongated groups of parallel microlites (fig. 2) appear to be one of the earliest stages in the development of the feldspar crystals in this case, and growth is analogous to that of the hornblende crystals described by Zirkel in the diorite from New Pass, Nevada. That the fulgurite is formed chiefly by the fusion of the groundmass of the rock is shown clearly also by the following chemical analysis made by Professor Clarke and Dr. Chatard in the laboratory of the U. S. Geological Survey. The amount of fulgurite obtainable from the hand specimens was very small and sufficient for only a partial analysis. The alumina and iron were estimated together, and the amounts of potash and soda were not determined.

	Fulgurite.	Groundmass.
Silica (SiO_2)	55·04	55·85
Alumina (Al_2O_3) } Ferric oxide (Fe_2O_3) }	28·99	22·95
		4·59
Lime (CaO)	7·86	8·41
Magnesia (MgO)	5·85	3·08
Potash (K_2O)		2·67
Soda (Na_2O)		2·16
Loss by ignition	1·11	0·52
	98·85	100·23

The groundmass was separated from the olivine, hypersthene, and all but a trace of the feldspar by means of Thoulet's solution, and the magnetite was removed from it by hydrochloric acid. The presence of a larger proportion of magnesia in the fulgurite indicates the fusion of some of the hypersthene.

Nearly all of the fulgurite is either superficial or confined to the lining of preëxisting cavities. This is what we should expect from the well known fact that electricity always spreads itself upon the surface of a body. A small portion of the fulgurite, however, seems to have been produced within the adjoining compact rock by fusing the groundmass. It occurs in small irregular nodules or strings, frequently full of bubbles and occasionally possessing a distinct fluidal structure approximately parallel to the course of the electric current. It is difficult to conceive how a distinct fluidal structure may have been produced in these small masses, which were but momentarily viscous and completely hemmed in upon all sides, unless it is due to the repulsion of the particles among themselves. It is

well known that particles electrified by a passing current repel each other most forcibly in the direction of the current, and this repulsion may perhaps explain the lines of motion in the enveloped fulgurite as well as those which are so prominent parallel to the length of the lightning tubes. To the same repulsion may be due, at least in part, the accumulation of fulgurite about the openings of small tubes upon the surface of the rock. In describing such accumulation one author has remarked that the tubes seem to have boiled over. The effusion of fulgurite from the tubes was doubtless facilitated by the expansion and forcible ejection of the air within the cavity. The heat developed in the rock by the lightning is only momentary and proportional to the electrical resistance. The high temperature of any individual crystal within the heterogeneous path of the current may depend chiefly upon the resistance which that mineral offers; for the elevated temperature is of so short duration that the increase due to conduction at any point would be small. The brevity of the whole operation indicates that the fulgurite is the product of fusion purely and not in any considerable degree due to the action of one part as a solvent upon another. On this account it is interesting to note that the order of fusion in the formation of fulgurite holds no definite relation whatever to the order of crystallization when the rock solidifies from a molten magma. The groundmass (last product of crystallization) with its numerous grains of magnetite (first product of crystallization) have yielded most readily to the heat developed by the passing current. Next to these the hypersthene shows the greatest amount of alteration, while the difficultly fusible feldspar exhibits but slight traces of modification and the infusible olivine remains wholly unchanged. So far as observations have yet been made upon the production of fulgurite by the fusion of a heterogeneous rock it appears that the amount of melting experienced by each ingredient depends chiefly upon its degree of fusibility.

Notwithstanding the valuable researches of numerous observers on the electrical characters of minerals too little is yet known to determine how important a factor the electrical resistance of each mineral may be in determining the composition of the fulgurite. On account of the diaphaneity of the conductor and the great strength of the current by which fulgurite is produced it affords an excellent opportunity for the study of electric fusion. The presence of a porous rock, rich in iron, upon a prominent, acutely pointed mountain-summit in a region of violent electric storms presents the most favorable condition for the extensive formation of fulgurite.

U. S. Geol. Survey, Washington, D. C., May 27, 1884.

ART. XXXIII.—*On the Paramorphosis of Pyroxene to Hornblende in Rocks;* by GEO. H. WILLIAMS.

IT has long been recognized that pyroxene and hornblende are two different crystallographic forms of essentially the same molecule, of which the former is most stable at high, the latter at ordinary temperatures. As early as 1824 Mitscherlich and Berthier melted tremolite at the potteries of Sévres and found that on slowly cooling the mass crystallized in the form of augite.[1] In 1831, G. Rose repeated the same operation with actinolite from the Zillerthal with the same result.[2] The constancy of this change at temperatures of fusion has also been abundantly verified by the more recent experiments of Professors Fouqué and Michel-Lévy of Paris, who found it impossible to artificially produce hornblende. In every case where this mineral was employed, it changed at high temperatures to augite.[3] In natural lavas hornblende crystals are frequently observed to have undergone alteration around their outer edge into an aggregate of minute augite and magnetite crystals.[4] This is probably due to a caustic action of the magma, which, on account of an increase of temperature, partially dissolves the completely crystallized hornblende individual. The same change is observed when any amphibole crystal is subjected for a time to the action of a fused basic rock.[5] Rose maintained that hornblende in lavas was always younger than the augite, having been formed at a lower temperature. Though further study has failed to altogether substantiate this statement, the significant fact remains that, while all attempts to produce hornblende artificially have thus far been unsuccessful, augite is readily obtained by simple fusion.

No less conclusive is the proof that at ordinary temperatures the augite molecules have a tendency to rearrange themselves in the hornblendic form. Here nature furnishes the evidence which the laboratory fails to supply. In 1831 G. Rose described crystals of hornblende, collected by him during his journey with A. von Humboldt to the Ural Mountains, which possessed the external form of augite.[6] Some of these were even found to have a core of true augite. At first they were regarded as instances of parallel growths of the two minerals, but subsequently Rose[7] himself gave the real explanation of their origin by showing that the hornblende, which was fibrous

[1] Pogg. Ann., xxii, p. 338, 1831. [2] Ib.
[3] Synthèse des minéraux et des roches, Paris, 1882, p. 78.
[4] K. Oebbeke: Neues Jahrbuch für Min., etc. I Beil. Bd., p. 474.
[5] Doelter and Hussak: Neues Jahrbuch für Min., etc., 1884, i, p. 24.
[6] Pogg. Ann., xxii, 1831. [7] Ib., xxxii, p. 617, 1834.

in structure, had evidently resulted from a gradual and often incomplete molecular change of crystals originally altogether augite, just as monoclinic crystals of sulphur may be observed to slowly pass out into an aggregate of orthorhombic individuals when subjected to circumstances different from those under which they were formed. Later, Rose[8] and others described this alteration of pyroxene, to which he applied the name uralite, from many other localities, and with the introduction of the microscope as an aid in studying rocks it was found to be exceedingly wide spread.

It is generally conceded that temperature is not the only influence which conditions the crystalline form assumed by the pyroxene-hornblende molecules. Hornblende is often observed as a primary constituent of certain (generally acid) lavas, and it seems probable that augite *may* be formed at comparatively low temperatures. The chemical constitution of the mass in which the crystals are formed, as well as other conditions not now understood, are doubtless influential. Nevertheless, the general tendency on the part of the pyroxene-hornblende molecules to attain a state of stable equilibrium seems to be in the manner described above, since no change of augite into hornblende at high temperatures, nor of hornblende to augite at ordinary temperatures, has ever been observed.

Quite recently the possible wide-spread geological importance of the paramorphosis of pyroxene to amphibole in accounting for the existence of many areas of hornblendic rocks by the alteration of other rocks, originally augite, has attracted much attention. This change has been carefully followed in Norway,[9] Austria,[10] Saxony[11] and several other European localities,[12] as well as on this continent in New Hampshire,[13] Wisconsin,[14] and in the region about Baltimore.[15] In a large majority of cases the change seems to be to true uralite. Hypersthene and diallage as well as common augite and even compact original hornblende undergo an alteration, extending from the outer edge of the crystal toward the center, into aggregates of hornblende fibers whose axes are sometimes approximately parallel to those of the original crystal, sometimes not. In the Baltimore gabbros a zone of white hornblende, resembling tremolite, is generally present between the pyroxene and the green

[8] Pogg. Ann., xxvii, p. 97, 1833.

[9] H. Reusch: Die fossilien-führenden Schiefer von Bergen, Norwegen, transl. by Baldauf, 1883.

[10] F. Becke: Tschermak Min. und Petr. Mitth., 1882, p. 157.

[11] J. Lehmann: Die altkrystallinen Schiefergesteine. Bonn, 1884, p. 190.

[12] Cf. A. Geikie in "Nature," June 5th, 1884.

[13] G. W. Hawes: Metadoleryte from Littleton, N. H. This Journal, III, xii, p. 136.

[14] R. D. Irving: this Journal, July, 1883.

[15] G. H. Williams: Johns Hopkins University Circulars, No. 30, April, 1884.

uralite, while the latter exhibits a marked tendency to become compact along its outer edge.

Instances of the change by paramorphosis of a pyroxene crystal directly into a single individual of compact hornblende, without the intervention of anything resembling uralite, have heretofore hardly been observed in sufficient perfection to place their nature beyond all doubt. Augite crystals more or less completely surrounded with a rim of compact hornblende have frequently been described, but almost universally regarded as parallel growths of two original minerals, just as Rose at first explained the occurrence of uralite.[16] That this may indeed be the true explanation in some cases is most probable, but I am convinced that in many instances it is insufficient. In 1878 Dr. G. W. Hawes[17] figured and described an occurrence side by side of augite and basaltic hornblende as an instance of paramorphism and the same interpretation was put two years later by Professor R. D. Irving[18] upon similar cases occurring in certain Wisconsin rocks. In neither of these instances, however, are the proofs of paramorphism adduced entirely convincing. Several cases therefore, recently noted by the present writer, where such a direct change of pyroxene to compact hornblende is admirably exhibited in every stage, seem worthy of a brief description.

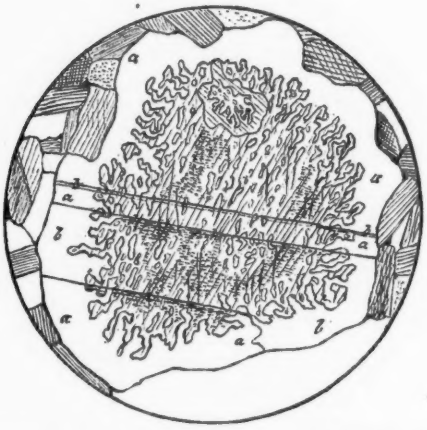
As members of that remarkable group of massive rocks exposed just south of Peekskill, on the Hudson River, to which Professor J. D. Dana has recently applied the name *Cortlandt Series*,[19] there are several apparently distinct types, occurring in the most intimate possible relations on the northern shore of Montrose Point. A microscopic examination, however, reveals the fact that these types are not in reality as distinct as they at first appear. They all consist largely of compact brown hornblende, together with more or less augite and hypersthene and a varying, though generally small proportion, of a basic feldspar. Their principal differences consist in coarseness of their grain and the relative amounts of the different bisilicates present. They were evidently all derived from one magma and exhibit very beautifully the structure termed by Fritsch and Reiss[20] "Eutaxitic," which is so commonly observed in acid lavas like trachyte and phonolite. All of these rocks which contain pyroxene show the direct change of this mineral to compact brown hornblende in an endless variety of cases. I shall only attempt to describe one or two where this process

[16] Pogg. Ann., xxii, 1831.
[17] Mineralogy and Lithology of New Hampshire, pp. 57, 206, Pl. VII, fig. 1.
[18] Geology of Wisconsin, iii, p. 170, 1880. Cf. Vanhise, this Journal, III, xxvi, p. 29, July, 1883.
[19] This Journal, III, xx, p. 194, Sept., 1880.
[20] Geologische Beschreibung der Insel Teneriffe, 1868, p. 414.

is especially apparent. These must serve as types of all the rest.

One rock from the locality just mentioned consists of an exceedingly fine-grained, jet black mass in which occasional bronze-colored crystals of hypersthene are easily visible to the unaided eye. The microscope shows the groundmass to be composed essentially of small oval grains of brown hornblende with here and there a similarly shaped crystal of hypersthene or plagioclase. The large porphyritic crystals of hypersthene are all undergoing paramorphosis to single individuals of brown hornblende. Fig. 1 represents one of these magnified thirty diameters. The interior portion is readily recognized under the microscope as hypersthene in which the characteristic inclusions are quite intact wherever the original substance is unaltered. The hypersthene core is surrounded by a zone of perfectly compact brown hornblende whose external boundary,

1.



while showing no signs of crystal planes, is only so far irregular as the development of the crystals of the groundmass lying adjacent to it requires. The interior boundary of this rim however, i. e. the line of contact between it and the hypersthene core, is the most irregular imaginable. The most delicate possible tongues and shreds of hornblende extend from the outer rim into the hypersthene in every direction, though they seem to be most developed in the direction of its cleavage. Moreover the entire surface of the hypersthene as displayed in the section, except in a few spots, where, as already observed, the characteristic inclusions remain, is covered with the same tongues and shreds of hornblende of a delicacy and tenuity

which it is impossible either to adequately describe or portray. The hypersthene and hornblende substance, which are well distinguished by differences of color and optical orientation, are not in reality separated by sharp lines of contact, as from the nature of the case it is necessary to represent them in a drawing in black and white. They everywhere shade into one another by insensible gradations. The transition is so gradual that it is often impossible to detect the exact point where it occurs even with the highest power of the microscope. Everything in the slide seems to indicate that a slow change from one mineral to the other is in progress, which has started at very many points throughout the entire body of the crystal and is only complete around its outer edge. A short examination of this section would, I think, be sufficient to convince any one that this is no instance of a parallel growth.

The optical orientation of this secondary hornblende is very remarkable, and shows conclusively that the alteration is to a single, perfectly homogeneous crystal, corresponding in all respects to the original hypersthene individual. Nowhere does the secondary mineral exhibit any signs of a fibrous structure. Even the smallest and thinnest particles are perfectly compact and all are identical in their optical behavior. The hypersthene crystal, as can be readily seen between crossed nicols, is a polysynthetic twin, consisting of several lamellæ. The position of the twinning trace, though not visible in ordinary light, has been indicated on the drawing. Curiously enough all the hornblende connected with the hypersthene has precisely the same optical arrangement. The larger middle portion, as well as the fine lamella (marked *b* in the figure) of both the hypersthene and hornblende are in twinning position to the two ends and the smaller middle portion (marked *a*), and all the particles of hornblende, whether around the edge or upon the surface of those hypersthene lamellæ having the same crystallographic position, extinguish the light between crossed nicols at the same instant, while all particles contiguous to the other hypersthene lamellæ are seen to be in twinning position with relation to them. The twinning trace divides the finest shred of hornblende as sharply as it does the hypersthene substance, and the narrow lamella, *b*, extends across the hornblende rim just as though it were part of the original crystal.

If additional proof were needed it would seem to be furnished by the smaller crystal of hypersthene inclosed in the upper part of the larger one. This exhibits in a smaller scale all the phenomena just described. It is also surrounded by a zone of compact hornblende, which evidently extends to the limits once occupied by the hypersthene. There are the same irregular patches of hornblende over the surface, but here, the

original crystal being simple, the secondary mineral all has the same optical orientation.

Fig. 2 exhibits a similar case of paramorphosis of augite to brown hornblende in another section of the same rock. The crystals are cut nearly perpendicular to their vertical axes and show very plainly that their orthopinacoids are parallel. The change has here taken place in somewhat larger patches than in the former instance and the boundaries between the two minerals are somewhat more distinct, but there can be little doubt that the process is the same in both.

These two cases described in some detail must be regarded as typical of a great variety of others, nearly or quite as good, which when taken together make the evidence of paramorphosis, at least as far as the particular rock in question is concerned, very satisfactory. It has been already mentioned that the groundmass of this rock is composed almost entirely of rounded

2.

grains of compact brown hornblende. Interspersed among these are frequent hypersthene grains of precisely the same shape and in every possible stage of transition to hornblende, which is apparently identical with that making up the bulk of the groundmass. The supposition, therefore, that this was originally a hypersthene rock (norite), like others which occur in close connection with it, and that its present form (diorite) has been due to gradual molecular alteration, seems quite natural, although not perhaps capable of rigid proof.

Several rocks from other localities have come to my notice which seem also to show strong indications of the direct change of pyroxene into compact hornblende.

Microscopic sections of gabbros from Eagle Harbor, Ashland Co., Wisconsin, the possession of which I owe to the kindness of Professor R. D. Irving, show the undoubted change of the pyroxene into single individuals of compact brown hornblende, as recently described by him,[21] although in none that I have examined is the change as plainly exhibited as in the rocks from Montrose Point. The wernerite-hornblende rock, in connection with which the apatite deposits of Scandinavia occur, have been recently studied by H. Sjögren,[22] who called them *dipyrediorites*. They are regarded by this author as a peculiar facies of a gabbro, formed from this by the paramorphosis of feldspar to wernerite and of pyroxene to hornblende. Both brown and green hornblende are produced in this way. I am indebted to Mr. Frank D. Adams, of the Canadian Geological Survey, for the opportunity to study a series of sections of both the Swedish rocks and others exactly like them, occurring in connection with the apatite deposits near the Ottawa River in Canada. All of these show the gradual change of pyroxene to compact green hornblende in a manner closely resembling that exhibited by the Cortlandt rocks.

The so-called "black granite" from Addison, Me., seems to have originally been an augite-plagioclase rock containing some biotite. The augite, however, is to a large extent undergoing paramorphosis to corresponding crystals of compact green hornblende, and so far has this process progressed, that the rock would now be classed as an augite diorite or at least as a proterobase. In the Baltimore gabbros the change of diallage to compact green hornblende has been observed, although far less frequently than that to uralite. Doubtless many cases which have been described by European lithologists as parallel growths of pyroxene and hornblende might be still better explained by paramorphosis.

Before leaving this subject it may not be uninteresting to inquire into a possible *cause* of the change, by molecular rearrangement, of pyroxene to amphibole. It is well known that dimorphous substances require different conditions for the assumption of their different crystalline forms. The molecular groupings, of which such forms are the outward expression, are not accidental but must always be in accordance with the circumstances under which they were produced. If the conditions most favorable for the assumption of one form are subsequently changed to such as are more favorable for the existence of the other, then the molecules are no longer in a

[21] Geology of Wisconsin, vol. iii, 1880. Third An. Report of the Director of the U. S. Geol. Survey, p. 105. Copper-bearing Rocks of Lake Superior. Monographs V.

[22] Geol. Fören. i Stockholm Förh., 1883, vi, 447. Cf. Neues Jahrbuch für Min., etc., 1884, I, ref. 81.

state of perfectly stable equilibrium. Were they free to move, they must at once rearrange themselves to suit the altered conditions, but if they have passed into the solid state, this tendency to rearrangement may not be sufficient to overcome the force of cohesion. Sometimes indeed, as in the case of monoclinic sulphur or arkansite, the crystal structure is actually pulled to pieces and the matter rearranged in accordance with existent circumstances. More frequently, however, the molecular tendency can only manifest itself in an optical disturbance. Mallard[23] has recently shown that crystals of boracite above 265° C. become altogether isotropic, and Klein[24] has argued from this fact that the mineral is dimorphous, crystallizing in the regular system above, and in the orthorhombic system below this temperature. Merian[25] has also shown that tridymite becomes optically hexagonal at high temperatures, and, according to Klein,[26] even leucite loses its twinning lamellæ and behaves like a regular mineral at a temperature considerably below its fusing point. The effort of the molecules to change their arrangement in accordance with the change of temperature here produces a tension, resulting in optical derangement but no new form.

In the case of the dimorphous pyroxene molecule there must be a similar tendency to assume the hornblende form, which, as we have seen, is the most stable one at ordinary temperatures. It is not probable, however, that this tendency alone would be sufficient to effect a complete change of crystalline structure. If, on the other hand, the assistance of some external agency could be introduced, which would render the molecules more or less mobile without increasing their temperature to a point where the augitic mode of arrangement is more stable than the hornblendic, it will readily be seen that they must assume the form best in accordance with the lower temperature. Just such an external agency as this would seem to me to be furnished by the *pressure* to which rocks are subjected in the formation of mountains. If hornblende is melted, the molecules become easily movable and a rearrangement naturally takes place to suit the altered conditions. The reverse of this process it would be very difficult to accomplish in the laboratory, but in nature it appears to be the commoner of the two. The recent experiments of Spring as well as the observations of Heim and others in the Alps, seem to indicate that pressure may cause molecular movements in solids without rupture, just as heat does. Of course this pressure produces heat but acting as slowly as it does in the elevation

[23] Bul. Soc. Min. de France, v, p. 144, 1882.
[24] Neues Jahrbuch für Min., etc., 1884, i, p. 185 ref., ib., p. 237.
[25] Ib., 1884, i.
[26] Nachrichten der kön. Ges. d. Wiss. Göttingen, May, 1884.

of mountains, there is no reason to assume that the actual temperature of the rocks is thereby raised to anywhere near the point of fusion. May not then the force which has elevated the mountain chains have been also an efficient cause of the paramorphosis of pyroxene in rocks? Certainly this idea gains great support from the exceedingly intimate association of schistose hornblende rocks with perfectly massive gabbros and diabases in many different localities. In the great gabbro area west of Baltimore the massive diallage and hypersthene rocks occur everywhere imbedded in and passing by gradual transitions into more or less schistose amphibolites, which differ from them mineralogically only in the crystalline form of the bisilicate constituent. These amphibolites have throughout the whole area a nearly parallel strike and dip, and many other facts, which cannot here be enumerated, indicate that their schistose structure is, like slaty cleavage, the result of lateral pressure. That the amphibolites have resulted from the paramorphosis of the pyroxene in the gabbros is abundantly proven both by microscopic study and their relations in the field, and the fact is very significant that throughout the area, as a rule *the schistose structure is developed in proportion to the completeness of the paramorphosis.*[27] This could hardly be explained except by the supposition that both were produced by the same cause. Unless a mass of rock were absolutely homogeneous, a lateral pressure exerted upon it would not act equally at every point. Wherever its action was greatest, there it would first tend to develop a schistose structure, perpendicular to the direction of pressure, and there too it would probably first render the paramorphosis of pyroxene to amphibole possible.

According to the recent very admirable descriptions by Dr. J. Lehmann[28] of the so-called "Flasergabbro" group near Rosswein and Penig in Saxony, the phenomena there exhibited are apparently very similar to those displayed by the gabbros near Baltimore. The action of lateral pressure was so great as in many cases to have caused an actual crushing of the massive diallage-hypersthene rock and the result has been a schistose amphibolite enclosing lenticular masses of unaltered gabbro.

The association of schistose hornblendic rocks with massive ones containing pyroxene is known at very many localities both in Europe and this country. Jukes long ago suggested that many areas of hornblende rocks might be accounted for by the alteration of old lavas, and this idea seems now to be

[27] The writer hopes soon, under the auspices of the U. S. Geological Survey, to be able to fully illustrate the very interesting relations existing between the Baltimore amphibolites and gabbros.

[28] Ueber die Entstehung der Altkrystallinen Schiefergesteine, etc., Bonn, 1884, p. 190, et seq.

fast gaining ground. It seems probable that we here have a wide-spread and very interesting phase of metamorphism, the alteration of one rock to another resulting from the change of crystalline structure in a dimorphous constituent, due to pressure and change of temperature from a higher to a lower.

It is not my desire to claim that pressure is the only cause of the paramorphism of pyroxene, or, indeed, that it is ever absolutely necessary. The range of observations is as yet too small to allow of any generalization. These thoughts are thrown out as suggestions and it will in future be interesting to note whether this change has taken place on as large a scale, if at all, in the rocks of undisturbed regions, as in those which show unmistakable signs of having been subjected to great pressure.

Johns Hopkins University, Baltimore, May 30, 1884.

ART. XXXIV.—*On the Southward ending of a great Synclinal in the Taconic Range;* by JAMES D. DANA. With a map (Plate III.)

[Read before the British Association at its session in Montreal.]

THE Taconic question, although American in its facts, bears no less profoundly on foreign than on American geology; for it is largely a question as to the age and origin of crystalline rocks. I have therefore thought the subject an appropriate one for a meeting of the British Association.

My stratigraphical work in the region of the Taconic Range, begun in 1870, I have continued during the last two years; and it is my purpose to present some of the results of my recent investigations.

The discussion with regard to the Taconic rocks has been greatly complicated, from the first, by Professor Emmons's extension of the term Taconic to the rocks of other regions besides those of the original Taconic, because they were *supposed* to be—not proved to be—*supposed* to be of the same age and system. My work has been among the *original* Taconic rocks, those of the Taconic Range and its bordering limestone, which, together, gave to geology, through Professor Emmons, the term Taconic and the first facts and conclusions on the subject; and of these alone I speak.

This Taconic Range extends along the western border of New England, between Middlebury in central Vermont on the north and Salisbury in northwestern Connecticut on the south, and encroaches by its western slopes a little on the State of New York. The distance between these points is about 150

miles. The line of ridges, after dwindling to a low narrow strip in Salisbury, continues on southward; and this continuation is geologically a part of the range, although it does not bear the name on maps; but of this more southern portion I do not now propose to treat.

The general conclusions presented by me in earlier papers, published in this Journal from 1872 to 1881, are fully sustained by my more recent studies, and I therefore briefly state them.

First: as to the rocks. The schistose rocks constituting the Taconic Range vary gradually, as we go from north to south, from argillyte or roofing slate and the smooth, faintly crystalline hydromica (or sericite) schist, to chloritic mica schist, and still coarser kinds of mica schist containing garnets and staurolites.

Secondly: as to the structure of the range. These schistose rocks constituting the range lie, in general, in synclinals or compound synclinals. In the narrower portions the beds dip eastward across from west to east, leaving it ambiguous whether the uplift is anticlinal, or synclinal, or monoclinal. But in other wider portions the beds of the two sides dip toward the axis of the range, and often at a small angle, thus exhibiting the fact that in such parts the structure is synclinal, and rendering it probable that it is so elsewhere.

Thirdly: as to the unity, or not, of the eastern and western limestone belts. These belts of crystalline limestone, one extending along the east side of the Taconic Range, and the other, less continuously, along the western, blend with one another through broad low regions or valleys crossing the Taconic line, and thus prove that they are portions of one formation.

Fourthly: as to the stratigraphical relations of the limestone and schist. The great limestone formation passes underneath the schist of the Taconic Range as a lower member in the mountain synclinals; and, consequently, the eastern and western limestone belts are outcrops of opposite sides of such synclinals. To give the proof on this point for a part of the range is one of the objects of this paper.

Fifthly: as to the age of the limestone and schist. The limestone, which is part of the Taconic system, and, as just stated, an underlying member, contains, at various points in central Vermont and eastern New York, shells, corals and crinoids of the Lower Silurian, ranging in age from the inferior divisions of the Lower Silurian to the superior. Hence, the schists of the Taconic synclinals, which overlie the limestone and are younger than it, are of *later* Silurian age, and probably of the age of the so-called Hudson River group or Upper Llandeilo flags.

The subdivision of the Taconic system into an *older* and a *newer* Taconic was first made by Professor Emmons, the propounder of the system. But the division was not based on any facts connected with the *original* Taconic rocks—those of the Taconic Range—but on the perplexing facts that beset the subject after additions of other Taconic rocks and regions had been made. No facts favoring in the least such a subdivision have been reported from the Taconic Range.

Among those broader portions of the Taconic Range in which the pitch of the beds is for the most part toward the axis of the mountain and in this fact bear positive evidence of a synclinal structure, there is the elevated region called Mount Washington, situated in southwestern Massachusetts and northwestern Connecticut. This Mt. Washington portion of the range is that referred to in the title of my paper—"*On the Southward ending of a great Synclinal in the Taconic Range;*" and to the description of it I now proceed.

Mount Washington rises boldly above the limestone plains and valleys adjoining it. Its length is about twelve miles, and its average width five miles. The limestone area on the east of it, in Sheffield, Massachusetts, and the bordering part of Connecticut, is nearly ten miles wide, and that on the west, in Copake, about three miles wide. The summit of Mount Washington (called Mt. Everett) has a height of 2,624 feet above the sea. The mean height of the extensive summit region is over 2,000 feet, and 1,300 feet above the limestone plains at its eastern, western and southern base.

The accompanying map shows, on a scale of 0·8 inch to the mile, the outline of the southern part of the mountain area of the schist (the part in Connecticut), and the limestone at its base: the portion shaded (by transverse lining) being that of the limestone.* The circles enclosing Fe indicate the localities of iron-ore pits. For the heights on the map I am indebted to Mr. Pettee, civil engineer and surveyor, of Lakeville, Conn.

There are also isolated ridges of schist in the limestone portion (the oblong white areas on the map); and there are a few small areas of limestone (lined on the map, like the rest of the limestone) within the region of the schist, one near Copake on the west side, and nine others in the southwestern part.

I will first state the facts which prove the structure of the mountain to be synclinal.

First. The dip, both of the schist and limestone, along the opposite sides of Mt. Washington in Massachusetts, is toward the axis of the mountain. On the west, the dip is eastward—usu-

* The map accompanying this article, presented to the British Association, included the whole of Mount Washington. I propose to publish soon a map of all of Berkshire, and another of Salisbury and Canaan, with full details.

ally between 30 and 60 degrees. On the east side, it is westward; in a large portion, only 10 to 25 degrees or not diverging widely from the horizontal, but in other parts ranging up to 45 degrees, and also to 60 and 70 degrees. (On the map the strike and dip are indicated by T-shaped symbols; the length of the stem of the T is inversely as the amount of dip, and the point of junction of the top and stem marks the locality of the observation.) In an east-and-west section through the highest point of the mountain (the peak, Mt. Everett, in Massachusetts,) the dip on the west side in Copake is 40 to 50 degrees eastward; at Mt. Everett, which is near the eastern border, 35 to 60 degrees westward; and at the base directly below, in Sheffield, 15 to 30 degrees westward. At the latter place [which is near the house of L. Roys] the limestone makes the lower 150 feet of the eastern front, and above it are the beds of schist, their cut edges making its face.

Figure 1 is a section of the beds at the western foot, and fig. 2 a section at the eastern.

My observations on the dip at other points in Massachusetts sustain the conclusion as to the synclinal character of the mountain-mass.* The synclinal is really a compound synclinal, that is, contains within it subordinate anticlinals and synclinals. This is suggested by the two limestone valleys running deeply into the mountain area on the north, and by the occurrence, within the area, near its southern border, of small limestone belts, as already pointed out.

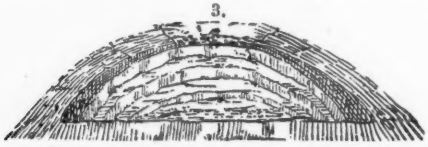
2. The general synclinal character of the mountain is indicated also about its southern extremity. In the southernmost of the small limestone areas in this part of the mountain, numbered 1 on the map, the limestone in one part was bare for a breadth only of a few yards, the mica schist overlying and concealing it on either side and to the south. Here a quarry was opened for the sake of the limestone, and consequently the cover of

* The following are some observed strikes and dips at the eastern base:

In Massachusetts, near the northern end, schist N. 35° W., 10°–15° W., and limestone, 40′ off, N. 55° W., 20°–25° W.; about 2 m. south, schist 15°–20° W., limestone N. 10° W., 15°–20° W.; 2 m. farther south, schist, about 25° W.; ¼ m. N. of the line of the State, schist N. 20° E., 50°–55° W., limestone, 75′ off same. In Connecticut, just south of line, at Sage's ravine, schist N. 20° E., 50°–65° W., limestone ¼ m. east, N. 22° E., 60°–70° W., but varying much. The dip of the schist increases southward, and a mile south is 90°, and two miles south has some easting; the limestone just east of it generally dips westward. (See map.)

schist was removed, so as to reveal the anticlinal position of the rocks. The schist now caps the limestone on all but the upper side, as shown in fig. 3, a view of the quarry. The dip of the

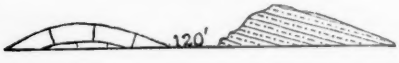
3.



limestone is southeastward in the eastern part, but southward in the southern, the latter being the direction of the axis of the little anticlinal.

In the limestone area No. 2, which is but a few rods from No. 1, there is another similar anticlinal of limestone; but the schist is not here seen in actual contact with the limestone,

4.



5.

owing to the soil between (fig. 4); and hence, although the dip indicates that the schist is the overlying rock, the case is not as satisfactory as the preceding. In another small area, No. 3, the limestone and schist are in contact, and dip together northward at the low angle of 20 degrees, as in fig. 5.

The other areas of the group are longer belts and have the dip of the limestone throughout eastward, and mostly 30 to 50 degrees; and since the limestone is the underlying rock, as number one indicates, they are all, if not monoclinal, as is hardly possible, small overturned anticlinals, which have had their tops worn off so as to show the limestone beneath. The very narrow strip, No. 9, the westernmost of the number, outcrops in the bottom of a small trench occupied by a brook, and the outcrop has a width of but three to four yards. The stream has here worn through the schist to the subjacent crystalline limestone. The handsome mottled coloring of the limestone has led to the designation of the place as a marble quarry, although no quarrying has yet been carried on.

3. The synclinal structure of the mountain is apparent also along portions of the southern edge of the schist. At Ore Hill, one and a half miles west of Lakeville (ore-pit *b* on the map) the schist overlies limestone; for the bed of limonite with which limestone occurs is reached by excavating through 40 to 60 feet of more or less decomposed schist—as may be seen on the southeast side of the ore-pit; while at the Chatfield

ore-pit (ore-pit *c*) 400 yards south, the schist fails, and only drift material covers the limestone and ore.

The ore-pits that have been opened about the base of Mt. Washington, fourteen in number, are situated near the junction of the limestone and schist; and, in view of the facts that have been mentioned, this means—*near where the limestone emerges from beneath the schist.* I here add that the iron ore (*limonite*, or, as the miners call it, *brown hematite*) has resulted from the oxidation of iron, the iron existing in some state of combination in the limestone and schist, and chiefly, I believe, in the limestone.

The facts presented appear to be sufficient proof that the structure of the Mt. Washington part of the Taconic range is synclinal.

The dying out of the Mount Washington synclinal southward has some features of special interest.

In the first place, the schist area abruptly narrows (as is seen on the map) along an oblique line through the village of Lakeville, from a breadth of four miles to that of six-tenths of a mile near Ore Hill.

In the second place, while the mountain three miles north of Lakeville is 1,200 feet high above the limestone, it is only 150 feet high in the narrow neck to which it is reduced near Ore Hill.

Again, the pitch in the beds in the last three miles is southward in some parts, instead of eastward or westward, showing a flattening out of portions of the synclinal and subordinate anticlinals. But these southward pitching surfaces alternate with others that have the usual northward strike. The variations in strike and dip are so frequent that the directions could not be indicated on a geological map unless it were made on a very large scale. The small areas of limestone in the southwestern portion, numbered 1 to 9, are, as already explained, the sites of some of the local anticlinals—of those of them which had the underlying limestone so near the surface that erosion has succeeded in exposing it to view.

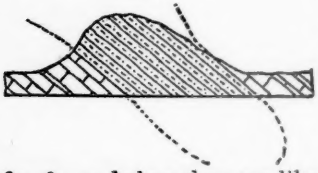
It thus appears that in the dying out of the synclinal, besides a flattening of portions of the general synclinal and the introduction of southward dips, there was also a multiplication of small subordinate flexures.

Further, there is a multiplication of ridges of schist in the limestone area.

Several such ridges, some quite small, are situated, as the map shows, southeastward of the mountain near the village of Salisbury; and others occur farther east. They consist of the same mica schist as the mountain, and look like fragments of

the same formation. They are not, however, horizontally-bedded fragments; for they have, generally, an eastward dip, often a high dip; and the facts seem to show that most of them are *synclinal* flexures; that they occupy the troughs of local synclinals in the limestone; that, as Mt. Washington consists of schist contained in a broad limestone trough, these isolated schist ridges, except in the case of an occasional monoclinal or anticlinal, occupy narrow troughs. Most of them were, apparently, half-overturned troughs, so pushed over westward that the dip of the schist is generally eastward, as illustrated in fig. 6; and thus they are like those of the Taconic Range just north of Mount Washington. The ridges to the southwest of Mount Washington are of like character, though larger and less numerous.

6.



The statement that these isolated ridges are for the most part synclinals, I could illustrate by numerous sections from other parts of the Taconic region; but this would lead me from the special subject before us, and I leave it for another occasion.

I close by enumerating some of the subjects illustrated by the facts that have been presented, and a few of the conclusions flowing from them.

1. The facts have illustrated the features of a mountain synclinal; its compound synclinal structure; its variations in character as it dies out. As the mountain is a *synclinal* with subordinate anticlinals and synclinals in its mass, so what is now a broad limestone area was (as I might make clear, if not so already) an area of *anticlinals* with subordinate synclinals and anticlinals; and the schist ridges occurring isolated in the limestone stand in general in the synclinal troughs of the limestone area.

2. As the schist is the overlying rock of the region, and exhibits the cut edges of its beds in the precipitous sides of the mountain above the limestone, this schist once spread over the limestone area; and the stratum, judging from the greatest height of Mt. Washington, was at least 2,000 feet thick.

3. The limestone, which spreads to a width of three miles about Copake, west of Mt. Washington, continues southward and southwestward by two lines to the Hudson River. The wider and more northern belt reaches the river at Poughkeepsie, having one break of three miles in its course, and at some points it contains well-characterized Lower Silurian shells,

corals and crinoids. This fact, paralleled with that of the occurrence of similar mountain-synclinals and Lower Silurian fossils in the Taconic region of Vermont, affords paleontological evidence of the Lower Silurian age of the limestone of the Mt. Washington part of the Taconic region; and, since the fossils are partly those of the Trenton period (or Llandeilo group), they make, as has been stated, the schist of the mountain to be that of the Upper Llandeilo flags or Hudson River group.

4. Since the schist of the mountain is not older than the Llandeilo flags, or the upper beds of the Lower Silurian, it follows that not only roofing slate, hydromica schist, and chloritic hydromica schist, but also coarse mica schists, garnetiferous and staurolitic, have been crystallized at as late a period in geological history as the close of the Lower Silurian.

5. These crystalline rocks were crystallized and rendered garnetiferous and staurolitic while lying in beds over a great limestone formation of Lower Silurian age, which also was at the same time rendered crystalline.

6. The making of the extensive ore-deposits (beds of limonite, some of them over 100 feet deep), through oxidation and the decay of rocks, could not have commenced before the close of the Lower Silurian; and, after the close, it would not have been commenced before an emergence of the rocks from the ocean had taken place, since air is needed, as well as water, for such oxidation. In view of the occurrence of limestones of the later Upper Silurian (Lower Helderberg group) overlying the upturned Lower Silurian and Cambrian slates of eastern New York near Hudson in Becraft's mountain and Mount Bob, and looking as if portions of a once extensive Upper Silurian formation covering much of New York State east of the Hudson River, it is probable that the emergence of the rocks from the ocean just referred to did not take place before the end of the Upper Silurian.

The conclusions I have presented as regards the synclinal character of Mount Washington and the rest of the Taconic range, and the Lower Silurian age of the rocks, is the same that was held and put forth by that most thorough and cautious geologist, the former able head of the Geological Survey of Canada, Sir William Logan.* The chief point of difference between us is that he, under the then existing paleontological evidence, made the limestone to precede instead of to include the Trenton group. In stratigraphical conclusions we are one.

* [Full credit to earlier and later authors who have published essentially the same view as to the stratigraphy, I have given in former papers, the latest in a paper in the Journal of the Geological Society of London for 1882.]

ART. XXXV.—*On supposed Glaciation in Pennsylvania south of the Terminal Moraine;* by H. CARVILL LEWIS, Professor of Geology in Haverford College. With a map (Plate IV, but not numbered.)

IN a "Report on the Terminal Moraine in Pennsylvania and Western New York,[1] I have said (p. 45) that "with the exception of a narrow district which I have called the *fringe*, the line of drift hills which crosses Pennsylvania lies at the precise edge of the drift-covered district," and (p. 43) that this terminal moraine is a "line separating the glaciated from the non-glaciated regions."

But in his letter of transmittal, Professor J. P. Lesley, the State Geologist, in referring to the limit of glaciation, makes the following statement:[2]

"Two remarkable phenomena, however, stand in the way of a positive and final assertion respecting the limit of the southward extension of the northern ice, in spite of the well-marked line of its terminal moraine, viz: scratches observed on the mountains of Schuylkill and Dauphin County; and vast grooves or notches in the crest of the Kittatinny mountain, for which no explanation is suggested by the drainage system of the country.

(1.) "Respecting the first very little can be said, but that little is important.

"In 1850–51 Professor Edward Desor of Switzerland, and myself, observed glacial scratches pointing southward upon the bare outcrop of conglomerate which makes the crest of Locust mountain west of Ashland. The testimony of the distinguished glacialist to their genuineness is sufficient. We were both of us perfectly well acquainted with the nature and aspect of 'slickensides' and felt sure that these polished surfaces, grooves, etc., were not of that kind, nor could they have been produced in that way; for they crossed the eroded edges of the beds.

(2.) "Some years afterward I observed horizontal grooves traversing the natural vertical east wall of the small and unique notch in the crest of the Fourth mountain where it is crossed by the turnpike from Harrisburg to Halifax. The opposite west wall had been cut to the vertical by the engineers, and was covered with sections of blast holes; but the east wall had not been touched, and was covered with *horizontal* glacial grooves and scratches crossing the deeply south-dipping bed-planes. In this case I had no one with me to verify the observation, but I feel as sure of the nature of the exhibition as in the former case. . . .

(3.) "The Wind Gap is one of the strangest and most inexplicable features of the earth's surface. . . . I am not aware that any

[1] Report Z. Second Geological Survey of Pennsylvania, Harrisburg, 1884.
[2] P. xli.

serious attempt has been made to construct a satisfactory hypothesis of its origin. . . . A long, straight, sharp-crested ridge, 1000 feet high on a base two miles wide, is here, not split by a fault, nor gapped by a stream, but worn smoothly through to half its altitude. The raggedness of the mountain crest ceases and smoothly rounded slopes descend to the smoothly rounded bottom of the gap which is lined with sand and gravel. . . It is evidently a deep cross-groove smoothly made and finished by some agent of erosion acting slowly and continuously—but an agent quite different from a river. . . . I can see no serious objection to the supposition that the front of the ice-sheet may at one time have advanced the necessary two miles and banked itself against the mountain at the Wind Gap. . . . In any future investigation of the origin of the Wind Gap the fact that there extends southward from the level of the bottom of the Gap, a fan-shaped sloping plain of rounded bowlder drift which has evidently all come through the Wind Gap, and has probably been brought through it by the agent which made the gap (although that cannot be taken for granted) must be taken into consideration."

Professor Lesley then repeats an explanation for the origin of the Wind Gap which he made in 1882, that it was due to the overflow of a vast lake which he supposed to cover a large part of Monroe and Carbon Counties, which lake was due to a great ice-dam at the Lehigh Water Gap. But as this dam would have had to be 1100 feet high in order to deliver the water over the crest of the mountain when the Wind Gap was begun, and as the glacier did not cover the region about the Lehigh Gap, he grants that such a supposition is untenable.

(4.) He then mentions a topographical feature six miles west of the Lehigh Gap, saying:

"It looks as if the bowl had been made by some kind of waterfall; but if so the mass of water must have been extraordinarily great and must have shot clear of the top of the mountain—an arrangement only possible in case the back valley were filled with ice to a height exceeding that of the mountain."

In addition to the passages just quoted, there are a number of other statements made by different geologists which describe further supposed evidences of glaciation in Pennsylvania south of the terminal moraine.

(5.) Mr. C. E. Hall has published two short papers which are also quoted in the preface to Report Z. In the first of these[3] he calls attention to the bending over of slate outcrops both north and south of the Lehigh Gap, which he regards as due to the southeastward movement of a glacier.

(6.) Mr. Hall also mentions a mass of debris a few hundred yards north of the gap, concerning which he says:

[3] Proc. Amer. Philos. Soc., xiv, 620.

"The only explanation I can give of this, is, that it is a moraine formed by the glacier after it had receded through the gap, possibly a lateral moraine."

He also believes that the Wind Gap shows evidence of the passage of a glacier.

(7.) In his second paper[4] entitled "On Glacial Deposits in West Philadelphia," he describes a gravel opening between Spruce and Walnut streets west of 45th street in West Philadelphia, where, having found bowlders of Oneida conglomerate, Medina sandstone, Triassic shales, and probably Clinton and Oriskany, as also a few pieces of trap, he says:

"From all these evidences I have concluded that this belt of drift deposit is no other than a glacial moraine formed by the Schuylkill glacier receding from the site of the city."

He states also:

"that the surface of the gneiss where laid bare is comparatively smooth, and shows evidence of having been polished, though so soft as not to retain the marks of glaciation."

(8.) Prof. F. Prime, Jr., has stated[5] that

"A glacial moraine may be traced from the Wind Gap in the Kittatinny Mountain through Ackermanville, Bangor and Williamsburg to Portland on the Delaware river. . . . West of the Wind Gap no glacial moraine can be seen so far as the Lehigh river. That it existed, however, there is little doubt, and was probably washed away again by aqueous action, to be re-deposited as modified drift," etc.

(9.) Again he says in the same communication:

"Another glacial moraine also exists in the Saucon Valley south of the Lehigh; it extends from Friedensville almost to Bingen station on the North Pennsylvania railroad."

(10.) In his report on Lehigh County,[6] the same geologist states that, "distinct evidences were obtained of glacial deposits," and records his conviction that

"the glaciers, coming through the gaps of Kittatinny Mountain and in places riding over its crest, came down to the South Mountain." In the statement that in Lehigh County glacial scratchings "were, with a single exception, nowhere found; the subsequent erosion of the soft slates of the Hudson River group, and of the soluble underlying limestones, having removed all traces of any scratches which may have existed" he appears to add strong evidence of the truth of his conviction.

[4] Proc. Amer. Philos. Soc., xiv, 633.
[5] Proc. Amer. Philos. Soc., xviii, 85.
[6] Report DD, pp. 75–77, 1878.

(11.) Prof. J. F. Carll in his valuable report on the Oil Regions[7] includes an extended discussion of the glacial drift, and holds that

"besides the main southward movement of the glacier, every feature in the Allegheny valley south of Olean shows an ice movement *toward the north*," and "as there is no red rock in the northern branch valleys and no northern detritus in the southern branch valleys, . . . it follows that the northern ice-flow, southward, met a southern ice-flow, northward, and both moved westward side by side."[8] He makes the origin of this northward flowing glacier in the "upper branch valleys of the Allegheny River in Potter and M'Kean counties," and believes[9] that the Salamanca "Rock City" was formed by glacial erosion.

These eleven localities, each lying south of the terminal moraine, some of them considerably so, are, I believe, the only ones in Pennsylvania south of that line which have been regarded as showing evidences of glaciation by geologists of acknowledged ability. Several local writers in the State have mistaken weathered trap bowlders for glacial erratics, or fallen into similar obvious errors,[10] but these are not worthy of mention.

If these statements, given in such detail, remain unquestioned facts, it must be granted that the "terminal moraine," so-called, is a misnomer, and that the evidences usually relied on to distinguish glaciated from non-glaciated regions are insufficient.

It seems to be of importance therefore, that any investigations of the terminal moraine should be supplemented by careful inquiries into all reported evidences of glaciation south of that moraine.

It is proposed, therefore, to review each of the above eleven statements in turn.

The accompanying map represents by small colored circles the approximate position of each of the localities of supposed glaciation south of the moraine, numbered in accordance with the following descriptive paragraphs.

(1.) The striæ on the crest of Locust Mountain west of Ashland, and south of Mt. Carmel, have been frequently referred to,[11] and since they lie "25 miles south-southwest of the great moraine (Berwick)" are of the highest importance.

I have crossed Locust Mountain in three places west of Ashland, have walked along its summit south of Mt. Carmel for a considerable distance, and have explored, on foot and by

[7] Report III. [8] Loc. cit., p. 379. [9] p. 390.

[10] History of Chester County, Smith and Futhey, p. 186. History of Bucks County, Davis, p. 438, etc.

[11] MacFarlane's American Geological Railway Guide, p. 102. Report G6, xvii, Second Geological Survey of Penn., etc.

driving, the valleys both north and south of the mountain for many miles in each direction. I have also carefully examined the sides and ledges of the mountain and, thanks to careful instructions and a diagram given me by Professor Lesley, believe that I have succeeded in finding the very spot where Professors Lesley and Desor saw the striæ.

I found no moraines, no till, not a single transported or scratched bowlder, no kames or terraces, and no striæ. There was not a single sign of glaciation, and both mountains and valleys were in all respects similar to other non-glaciated mountain regions about the anthracite coal basins.

The mountain is formed mainly of Pottsville conglomerate (No. XII), a coarse white conglomerate with often large pebbles, and here characterized by numerous impressions of an unusually large calamite, probably *Calamites dubius* Artis (*Calamites bistriatus* Lesq.).

The impressions of this calamite are sometimes two to three feet long and from one to three inches in width, and are marked by a series of narrow parallel furrows, running longitudinally. The articulations are unusually distant and the parallel lines well marked. The impressions of this calamite are flat or only slightly rounded, often entirely colorless, no trace of the original fossil remaining, and, appearing often merely as a set of parallel lines crossing a face of conglomerate, have probably been mistaken for glacial striæ. The impressions of these calamites occur on the very ledge near the top of the mountain south of Mount Carmel which was supposed to be glaciated.

(2.) On the summit of Peters (Fourth) Mountain, where the Dauphin and Halifax turnpike crosses the sharp crest, is a small notch, some 15 feet deep, the east and west sides of which are nearly vertical walls of Pocono sandstone. The sandstone dips 65° S. 10° E., and there is a small coal vein in it part way down the mountain. After an examination of the region between here and Harrisburg, including the slopes and crest of the mountain, I was unable to find any trace of glacial action. The east wall of the notch is covered by numerous horizontal striæ, as stated by Professor Lesley, but these striæ are not of glacial origin, but are undoubtedly *slickensides.* The slickensides occur on the cleavage planes of the sandstone, these cleavage planes being at about right angles with the plane of bedding. Unlike a glaciated surface, the rock forms projecting angular crags, with irregular faces, cut by a series of cleavage planes, on several of which the slickensides appear. The slickensides do not make continuous lines nor occur on a single plane, thus differing from glacial striæ. Nor do they occur only on the surface, but run in *between* blocks of sand-

stone not yet separated. I hammered down some of these blocks and found the slickensides quite as well marked on the inner surface of the block just detached as they were on the vertical wall. This locality is over sixty miles south of the terminal moraine.

(3.) When studying the limits of glaciation in 1880 and 1881, I was aware of the statements that had been made concerning glacial action at the Wind Gap, and took special care to examine that locality thoroughly, particularly as it lies so near the terminal moraine. Within three miles of the gap, glaciation is proved by undoubted evidences. Scratched and transported bowlders, some of them of Adirondack granite, polished and striated rock surfaces, unmodified *till*, glacial lakes, kames and moraines, are all close at hand, but all stop suddenly at a point less than three miles away. I did not see a single scratched or transported bowlder in the gap, nor any striæ or other signs of glaciation. A long trench made for a projected railroad had been cut in the bottom of the gap, offering an excellent opportunity to study the character of the debris at that place. It presented no evidence of glacial action. The fragments were mostly angular, and composed of the same Medina sandstone (No. IV) which formed the two sides of the gap. They had evidently fallen there from the mountain. The "smoothly rounded slopes" referred to showed no evidence of glacial or aqueous erosion, their form being due to the mass of angular frost-broken talus which covers some of the crags.

North of the Gap, and at nearly the same level, the soil is filled with fragments of Clinton red shale and sandstone (No. V), being made of the underlying rock. No rounded or transported bowlders were here seen, although cliffs of Helderberg limestone and Oriskany sandstone occur immediately north. A few miles to the northeast, however, in the glaciated region, large blocks of both of these formations are strewn in abundance along the northern flank of the mountain.[12]

Nor could any "fan-shaped sloping plain of rounded bowlder drift" south of the gap be discovered. It is true that the whole valley south of the gap is strewn with water-worn rounded bowlders and with beds of clay, both of which were brought by waters issuing from the melting glacier a few miles eastward. I have been able to trace the course of a wide river, which, issuing from the base of the glacier west of Bangor, flowed westward past Pen-argil and Hellerville into the valley of Bushkill Creek, and thence to the Delaware. Another great stream flowed down the valley of Martin's creek, while at the same time there was a large sub-glacial drainage backward to Portland, as shown by the Portland kame.[13] The bowlders and

[12] V. Report Z, p. 88.

[13] Z, p. 69.

the bowlder-bearing clay which cover a great part of Northampton County south of the Wind Gap have clearly not come through the gap, but from the glacier on the south side of the mountain.

Immediately in front of the gap there is a great mass of sharp, frost-broken talus of Medina sandstone, which forms a sloping plain leading up to the gap. The rock fragments are not rounded or water-worn, but angular and often of large size. I am led to believe that all this work was accomplished long before the Glacial epoch.

An example on a small scale of the power of waters to carry sandstone blocks far away from their original outcrop, may be profitably studied within a few miles of Philadelphia, near King of Prussia, a locality which I briefly described some years ago.[14]

The Wind Gap does not seem to require any unusual or extraordinary origin. Like most mountain gaps, it appears to be the result of long continued pre-glacial erosion.

Its smooth outlines seem to me to be due to the uninterrupted course of atmospheric influences. Had a stream flowed through it in recent times, the talus would have been carried off and the sides of the gap become steep, as at the neighboring Delaware and Lehigh Gaps.

Still another consideration bears against the idea that the Wind Gap was cut down by a glacial stream.

A number of studies at points along the extreme edge of the glaciated area, where the moraine crosses river valleys, have led me to believe that neither the glacier at its cap nor the waters issuing from it have been able materially to modify the topography. In many cases the terminal moraine lies on the very floor at the bottom of a narrow valley. Had the glacial or post-glacial waters been able to excavate such a valley, the moraine would now lie *above* the stream. As instances, we have the moraine crossing the valleys of Fishing Creek, Columbia County; Great Valley Creek, Cattaraugus Co., N. Y.; the Susquehanna, Allegheny, Conewango, and Beaver Rivers. The evidence gathered from the conditions, on these and many other streams, is all opposed to any theory that the Wind Gap was made either by glacial waters or by ice.

(4.) The same arguments, that have been used in referring to the Wind Gap, are just as appropriate in considering the extraordinary hypothesis proposed to account for the Bake-oven. There is the strongest proof of the absence of all glacial action at this place. I find no evidence that the glacier approached the Bake-oven nearer than twenty miles.

(5.) The Lehigh River was one of the great waste-weirs of the melting glacier. All the way from Hickory Run, where

[14] Proc. Acad. Nat. Sc., 1880.

the moraine crosses it, down to its junction with the Delaware, heavy masses of water-borne drift mark the ancient flood, and show that it was 200 feet in depth. Where the banks of the river are steep, as they generally are as far down as the Lehigh Gap, the drift is represented by scattered bowlders only, all the rest having been washed away. Just north of the gap, for example, at a point one mile below Weissport, I found a large rounded bowlder of conglomerate six feet long lying upon a bank of shales of VIII, at an elevation of 150 feet above the river. Smaller ones occur up to a height of 180 feet. But south of the gap, where the easily eroded slates of III form an open rolling country, large masses of bowlders imbedded in a yellow brick clay cover the region on both sides of the river in beds sometimes more than ten feet deep. This deposit differs from glacial till in the rounded character of its bowlders, in the greater preponderance of clay, and in its more or less evident stratification. It certainly cannot be said to have "all the characteristics of a glacial deposit." It overlies Hudson River slate which, as Mr. Hall observed, is broken and crushed over, though not by a superincumbent glacier. The decomposed slates were naturally bent and crushed as the bowlder-laden flood crushed over them. Other cases could be cited at localities fifty miles farther south. A similar occurrence above the Lehigh Gap, also described by Mr. Hall, is of like character and origin.

(6.) The mass of debris across the mouth of the Aquanchicola Creek, supposed by Mr. Chance and Mr. Hall to be a moraine, has none of the characters of a moraine, either topographically or internally. Such accumulations are common at the meeting of two drift-laden streams. The materials are water-worn, and the bank is leveled off by water, presenting none of the contours of a true moraine. I could find no trace of glaciated surfaces anywhere in the vicinity. There is in fact nothing to indicate that this bank of drift is at all unusual or different from the other deposits along the Lehigh, which are the evident result of aqueous deposition.

On the so-called "Eddy-hill" just north of the Lehigh Gap I found no rounded stones or drift of any kind, and there is nothing to indicate that this conical hill made of Clinton red shale has been materially modified in shape since pre-glacial times.

(7.) In a former paper[15] I have endeavored to show that Mr. Hall was mistaken in supposing that there is a glacial moraine in West Philadelphia. The gravel deposit at that locality is identical with that which occurs all along the Delaware from Trenton to Wilmington, and belongs to what I have called the

[15] The Surface Geology of Philadelphia and vicinity. Proc. Acad. Nat. Sc., 1880.

"Philadelphia brick clay" and the "red gravel." It is a stratified deposit made at a time when this region was submerged to a depth of about 180 feet, and is bordered by the "Upland Terrace." It is, I believe, also a mistake to state that the underlying gneiss shows signs of polishing. As elsewhere about Philadelphia the gneiss is decomposed, and some of the decomposed portion has been mingled with the lower strata of the gravel. At many localities in the vicinity the gravel may be seen lying on very uneven surfaces of gneiss quite unlike the floors beneath true till.

(8.) Professor Prime has very naturally confounded the true moraine at Bangor and Ackermannville with the *Kame* which runs through Williamsburg (Mt. Bethel) and Bangor.[15] The topographical features of kames and moraines are very similar, and without a special examination of their internal structure are liable to be confounded.

(9.) The supposed moraine in the Saucon valley is merely a deposit of stratified drift, similar to those already described on the Lehigh and at Philadelphia. The bowlders are water-worn, not scratched, and lie at an elevation less than 180 feet above the river at Bethlehem.

(10.) Professor Prime's remarks about glaciation in Lehigh and Northampton Counties, south of the terminal moraine, prove to be due to the difficulty of distinguishing at times, between glacial *till* and aqueous deposits. It is true that as the glaciated area is approached from the south, the stratified surface deposits become very like true glacial drift. The bowlders become more numerous and larger, and stratification is not so evident. Occasionally also striæ are seen on the bowlders, especially in the larger river valleys, where the water was deep enough to float icebergs. Both Professor I. C. White and myself have experienced some difficulty of this kind in the valley of the Susquehanna, southwest of Berwick. But the absence of typical till, of striæ, and of moraines, and the fact that the deposits south of the terminal moraine are limited to districts below a fixed elevation, serve to distinguish them. I do not here include that, as yet, unexplained phenomenon which, more clearly shown in the western part of the State, I have called "*the fringe.*"

As to the glacial striæ in Lehigh County, Professor Prime has admitted to me that his reference to them was due to a mistaken observation.

(11.) The only evidence upon which Professor Carll rests his conclusion as to the northward flow of a McKean County glacier, appears to be[16] the occurrence of pebbles and bowlders of the red rocks of the Mauch Chunk (XI), Pocono (X) and

[15] v. Report Z, p. 52, 53, 62. [16] Report III, p. 379.

Catskill (IX) formations in the valley of the Allegheny river at Olean and Allegany, the rocks mentioned occurring only to the south of these towns. But he seems to forget that the Allegheny river flows northward to these points, and that it is just as capable of carrying rock debris northward as the Delaware is of carrying it southward. There is no necessity for a glacier as a transporter.

I have made a careful examination of the high region which Professor Carll would make a glacial center, and have found in it no trace of glaciation. No smoothed rock surfaces, no striæ, no till, no perched erratics, and no striated pebbles were noticed in McKean County, which I believe to have completely escaped the glaciation that has invaded every other county of the northern tier in this State. The Salamanca "Rock City," which Mr. Carll thinks was cut down by a stream of ice, is a remnant of a nearly horizontal sheet of Pottsville conglomerate (XII). It lies just south of the moraine and probably within the "fringe." But that it is due either to the glacier or to the glacial floods is extremely improbable. "Rock cities" like "pulpit rocks" and "monument parks" are characteristic of a non-glaciated region, where long continued atmospheric erosion has been uninterrupted either by glaciers or floods. The well known function of a glacier is to obliterate angular prominences, not to create them. I have been able to find no glacial marks of any kind at the Salamanca Rock city, nor any evidence that its origin was different from that of the Olean Rock city or similar phenomena elsewhere in the non-glaciated district.

In conclusion, I may perhaps be permitted to say that, while regretting the necessity of making personal allusions to those for whom I have the highest regard, I have felt it to be necessary both in answer to certain requests that have been made,[17] and also as a vindication of my deduction as to the truly terminal character of the Pennsylvania moraine.

Germantown, Pa., July 28, 1884.

ART. XXXVI.—*On a mass of Meteoric Iron from Wichita County, Texas;* by J. W. MALLET.

THE following is the history of the Wichita County meteoric mass, as given me by Hon. Henry P. Brewster, Commissioner of Insurance, Statistics and History of the State of Texas, a gentleman whose personal knowledge of the State in its early days is extensive and accurate.

The meteorite was found on the upper waters of Red River, in what is now the county of Wichita, not far from the Red River

[17] *Science*, vol. ii, No. 41, p. 654.

itself, on the opposite side of that stream from the part of the Indian Territory at present set apart for the Kiowas, Comanches and Apaches. It had been set up as a kind of "fetich" or object of worship or veneration by the Indians, "who revered it as foreign to the earth and coming from the Great Spirit," at a point where several converging trails indicated periodical visits to the spot. In 1858 or '59 Maj. Neighbors, then commanding at Fort Belknap, sent a wagon after the mass, and had it brought into the fort. It was thence sent in a government wagon to San Antonio, and subsequently moved to Austin, and there deposited in the old Capitol building, where it remained until the destruction of the building by fire some three years ago. Removed from the ruins, it was placed in a passage on the ground floor of the temporary Capitol now in use while the new and very handsome structure, intended for the permanent seat of the State government, is being erected. During last winter the meteorite was turned over by the State authorities to the University of Texas, and is now preserved in the University building at Austin.

The mass has an irregular, elongated pear-like shape, somewhat flattened, a good deal larger at one end than the other, with tolerably smooth general surface, but with well marked concavities or shallow pittings—in every way presenting the appearance of a typical metallic meteorite. There is no well-defined crust, but merely a thin, closely adhering film of oxide on the surface. There is no appearance of any effect from the Capitol fire through which it passed; very probably the weight of the mass may have carried it rapidly, on the giving way of the floor, down to some position in the basement in which it was sheltered from the heat by masonry rubbish accumulated over it. The dimensions of the specimen in its original state were—

Maximum length	595	millimeters.
Maximum breadth	305	"
Maximum thickness	223	"

The weight was a little under 160 kilograms, as determined on a rather rough platform balance.

A piece was cut off one end in order to display the character of the interior. Most of the iron was compact, and tolerably soft, tough and malleable. Here and there occurred nodules of troilite of considerable size, the principal ones ranging from 5 or 6 up to 23 millimeters in diameter. Signs of the presence of thin plates of schreibersite could be seen even without the use of acid, but that ingredient is not very abundant. The average specific gravity of the whole mass was probably pretty fairly represented by that of a slice weighing 204 grams, which was found $=7{\cdot}841$ at 24° C.

A polished surface having been etched with nitric acid, Widmannstättian figures were clearly brought out, the broad bands of crystalline nickel-iron (with finer subordinate markings upon them) contrasting strongly with the more sparingly occurring, well-defined, lustrous lines of schreibersite.

Chemical analysis of an average sample of the shavings taken off by a planing machine in cutting through the mass gave :

Iron	90·769	
Nickel	8·342	
Cobalt	·265	
Manganese	*trace*	
Copper	·018	
Tin	·004	
Phosphorus	·141	*
Sulphur	·016	*
Graphitic carbon	·190	
Silica	·132†	
Magnetic oxide iron		
	99·877	

A separate examination of the troilite nodules proved them to consist of ferrous sulphide with a little nickel and traces of manganese and chromium. The nickel may very possibly have existed in the form of minute granules of nickel-iron or schreibersite, and the chromium may in like manner be referred to an admixture of little particles of daubréelite.

The most interesting point about this specimen is perhaps the probability of its forming a separate portion of the same meteoric fall from which was derived the large iron meteorite, weighing 1635 lbs., first described by Col. Gibbs in 1814, and which has long been a prominent object in the mineralogical collection of Yale College at New Haven, Connecticut. The latter is said to have been found "near the head of Trinity River, a few miles west of the Cross Timbers, Texas, lat. 32°7′, long. 95° 10′ west of London." It is said to have been "one of a large number of meteoric masses which are reported to exist at the locality mentioned above." The statement of locality is not quite clear ; the spot designated by latitude and longitude is in the northern part of the present Cherokee County, near the line of Smith County, and rather on the head waters of the Neches than of the Trinity, though not far from the latter, and about 240 miles from the locality in Wichita County where the meteorite now described was found. Even such a distance

* Both of course variable with the distribution of schreibersite and troilite.

† Silica perhaps originally present as iron silicide—magnetic oxide iron doubtless from outside surface.

perhaps does not altogether exclude the idea of simultaneous fall, and it is of course quite possible that the mass found to be regarded with attention and veneration by the Indians may have been by them carried to the spot where they afterwards preserved it. There seems to be some uncertainty as to how many meteoric irons from Texas have before now been noticed, and are to be found in the mineralogical collections of the world. In a catalogue of the collection of Professor C. U. Shepard, published in 1857, in the second part of his treatise on mineralogy, p. 436, there is mentioned a meteoric iron from "Texas (Red River), U. S. A., found in 1808." In Rammelsberg's *Handbuch der Mineralchemie* (Leipzig, 1860) are noticed, p. 917, specimens from "Red River in Louisiana," and from "Texas," with the statement that according to Partsch these are probably identical; this opinion is undoubtedly correct; the analyses quoted show that both represent the Yale College specimen. In the recent (1880) catalogue of meteorites in the collection of the Indian Museum at Calcutta, No. 108 is quoted on p. 38, as two specimens from "Red River, Texas, U. S. A., found in 1814," No. 27, on p. 31, as a specimen which "apparently has been fired, from Denton County, Texas, U. S. A., found in 1856," and No. 39, on p. 32, as from "Brazos River, Texas, U. S. A., found in 1856." It may be questioned whether Nos. 27 and 39 refer to portions of the same or of different masses; the same date is given, but the shortest distance from any part of Denton county to the Brazos is about 40 miles, this county being traversed by affluents of the Trinity. The specific gravity of the iron now described agrees closely with that reported for the Gibbs meteorite of the Yale College collection. The results of the chemical analysis are also very similar to those obtained for the latter by B. Silliman, Jr. and Hunt. It is stated that this latter "encloses a few small masses of magnetic pyrites;" this statement probably referring to troilite nodules like those which are conspicuous enclosures in the University of Texas specimen. The Widmannstättian figures developed by etching this University of Texas iron do not closely resemble those of the Yale College specimen, as shown in a lithographed figure published in connection with the (Göttingen) inaugural dissertation on metallic meteorites of Wm. S. Clark (1852), copied from one published by Professor B. Silliman, Jr., but the difference of appearance may be largely due to difference in the planes of section in relation to those of crystallization in the particular pieces submitted to the etching process.

University of Virginia, August 11, 1884.

ART. XXXVII—*Jean-Baptiste-André Dumas;* by J. P. COOKE.*

JEAN-BAPTISTE-ANDRÉ DUMAS was born at Alais, in the south of France, July 14, 1800. His father belonged to an ancient family, was a man of culture, and held the position of clerk to the municipality of Alais. The son was educated at the college of his native place, and appears to have been destined by his parents for the naval service. But the anarchy and bloodshed which attended the downfall of the First Empire produced such an aversion to a military life that his parents abandoned their plan, and apprenticed him to an apothecary of the town. He remained in this situation, however, but a short time; for, owing to the same sad causes, he had formed an earnest desire to leave his home, and, his parents yielding to his wish, he traveled on foot to Geneva in 1816, where he had relatives who gave him a friendly welcome, and where he found employment in the pharmacy of Le Royer.

At that time Geneva was the center of much scientific activity, and young Dumas, while discharging his duties in the pharmacy, had the opportunity of attending lectures on botany by M. de Candolle, on physics by M. Pictet, and on chemistry by M. Gaspard de la Rive; and from these lectures he acquired an earnest zeal for scientific investigation. The laboratory of the pharmacy gave him the necessary opportunities for experimenting, and an observation which he made of the definite proportions of water contained in various commercial salts, although yielding no new results, gained for him the attention and friendship of De la Rive. Soon after we find the young philosopher attempting to deduce the volumes of the atoms in solid and liquid bodies by carefully determining their specific gravities, and thus anticipating a method which thirty years later was more fully developed by Hermann Kopp.

About this time, young Dumas had the good fortune to render an important service to one of the most distinguished physicians of Geneva, whose name is associated with the beneficial uses of iodine in cases of goitre. It had occurred to Dr. Coindet that burnt sponge, then generally used as a remedy for that disease, might owe its efficacy to the presence of a small amount of iodine; and on referring the question to Dumas, the young chemist not only proved the presence of iodine in the sponge, but also indicated the best method of administering what proved to be almost a specific remedy. It was in connection with this investigation that Dumas's name

* From the Proceedings of the American Academy of Science vol. xix, Boston, 1884.

first appears in public. The discovery produced a great sensation, and for many years the manufacture of iodine preparations brought both wealth and reputation to the pharmacy of Le Royer.

Soon after, Dumas formed an intimacy with Dr. J. L. Prévost, then recently returned from pursuing his studies in Edinburg and Dublin, and was induced to undertake a series of physiological investigations, which for a time withdrew him from his strictly chemical studies. Several valuable papers on physiological subjects were published by Prévost and Dumas, which attracted the notice of Alexander von Humboldt, who on visiting Geneva, in 1822, sought out Dumas and awakened in him a desire to seek a wider field of activity than his present position opened to him. In consequence he removed to Paris in 1823, where the reputation he had so deservedly earned at Geneva won for him a cordial reception at what was then the chief center of scientific study in Europe. La Place, Berthollet, Vauquelin, Gay-Lussac, Thenard, Alexandre Brongniart, Cuvier, Geoffroy St. Hilaire, Arago, Ampère, and Poisson, all manifested their interest in the young investigator. Dumas was soon appointed Répétiteur de Chimie at the École Polytechnique, and also Lecturer at the Athenæum, an institution founded and maintained by public subscription for the purpose of exciting popular interest in literature and science; and from this beginning his advancement to the highest position which a man of science can occupy in France was extremely rapid.

In 1826 he married Mdlle. Herminie Brongniart, the eldest daughter of Alexandre Brongniart, the illustrious geologist, an alliance which not only brought him great happiness, and at the time greatly advanced his social position, but also in after years made his house one of the chief resorts of the scientific society of Paris. The many who have shared its generous hospitality will appreciate how greatly, for more than half a century, Madame Dumas has aided the work and extended the influence of her noble husband.

1828–29 Dumas united with Théodore Olivier and Eugène Péclet in founding the École Centrale des Arts et Manufactures, an institution which met with great success; in which, as Professor of Chemistry, Dumas rendered most efficient service for many years, and in 1878 had the very good fortune to aid in celebrating the fiftieth anniversary of his own foundation, and to see it acknowledged as among the most important and efficient scientific institutions of the world. In 1832 Dumas succeeded Gay-Lussac as Professor at the Sorbonne; in 1835 he succeeded Thenard at the École Polytechnique; and in 1839 he succeeded Deyeux at the École de Médecine. Thus

before the age of forty he had filled successively, and for some time simultaneously, all the important professorships of chemistry in Paris except one. This exception was that of the College of France, with which he was never permanently connected, although it was there that he delivered his famous course on the History of Chemical Philosophy, when temporarily supplying the place of Thenard.

Dumas early recognized the importance of laboratory instruction in chemistry, for which there were no facilities at Paris when he first came to what was then the center of the world's science; and in 1832 founded a laboratory for research at his own expense. This laboratory, first established at the Polytechnic School, was removed to the Rue Cuvier in 1839, where it remained until broken up by the revolution of 1848. The laboratory was small, and Dumas would receive only a few advanced students, and these on terms wholly gratuitous. Among these students were Piria, Stas, Melsens, Leblanc, Lalande, and Lewy, with whose aid he carried on many of his important investigations. By the Revolution of 1848 Dumas's activities were for a time diverted into political channels; but under the Second Empire his laboratory was re-established at the Sorbonne, and in 1868 was removed to the École Centrale.

The political episode of Dumas's life was the natural result of an active mind with wide sympathies, which recognizes in the pressing demands of society its highest duties. The political and social upheaval of 1848 seemed at the time to endanger the stability in France of everything which a cultivated and learned man holds most dear; and Dumas was not one to consider his own preferences when he felt he could aid in averting the calamities which threatened his country. Immediately after the Revolution of February, he accepted a seat in the Legislative Assembly offered him by the electors of the Arrondissement of Valenciennes. Shortly afterwards the President of the Republic called him to fill the office of Minister of Agriculture and Commerce. During the Second Empire he was elevated to the rank of Senator, and shortly after his entrance into the Senate he became Vice-President of the High Council of Education. In order to reform the abuses into which many of the higher educational institutions of Paris had fallen, he accepted a place in the Municipal Council of Paris, over which he subsequently presided from 1859 to 1870.

In 1868 Dumas was appointed Master of the Mint of France, but he retained the office only during a short time, for with the fall of the Second Empire, in 1870, his political career came to an abrupt termination. The Senate had ceased to exist, and in the stormy days which followed, the Municipal Council had naturally changed its complexion; and even at the Mint, the

man who had held such a conspicuous position under the Imperial government was obliged to vacate his place. Some years previously he had resigned his professorships because his official positions were incompatible with his relations as teacher, and now, at the age of seventy, he found himself for the first time relieved from the daily routine of official duties, and free to devote his leisure to the noble work of encouraging research, and thus promoting the advancement of science. He had reached an age when active investigation was almost an impossibility, but his commanding position gave him the opportunity of exerting a most powerful influence, and this he used with great effect. In early life he had been elected, in 1832, a member of the Academy of Sciences in succession to Serullas; in 1868 he had succeeded Flourens as its Permanent Secretary; and in 1875 he was elected a member of the French Academy as successor to Guizot, a distinction rarely attained by a man of science.

It was, however, as Permanent Secretary of the Academy of Sciences that Dumas exerted during the last years of his life his greatest influence. He was the central figure and the ruling spirit of this distinguished body. No important commission was complete without him, and on all public occasions he was the orator of the body, always felicitous, always eloquent. In announcing Dumas's death to the Academy, M. Rolland, the presiding officer, said: —

"Vous savez la part considérable que Dumas prenait à vos travaux et vous avez bien souvent admiré, comme moi, la haute intelligence et la tact infini avec lesquels il savait imprimer à nos discussions les formes modérées et courtoises inhérentes à sa nature et à son caractère. Sous ce rapport aussi la perte de Dumas est irréparable, et crée dans l'Académie un vide bien difficile à combler. Aussi, longtemps encore nous chercherons, à la place qu'il occupait au Bureau avec tant d'autorité, la figure sympathique et vénérée de notre bienaimé Secrétaire perpétuel."

And while Dumas was still occupying his conspicuous position in the Academy, one of the most distinguished of his German contemporaries * wrote of him: "An ever-ready interpreter of the researches of others, he always heightens the value of what he communicates by adding from the rich stores of his own experience, thus often conveying lights not noticed even by the authors of those researches."

When the writer last saw Dumas, in the winter of 1881–82, the great chemist had still all the vivacity of youth, and it was

* A. W. Hofmann, in Nature, February 6, 1880, to whose admirable and extended biography the writer is indebted for much of the material with which this notice has been prepared.

difficult to realize his age. He took a lively interest in all questions of chemical philosophy, which he discussed with great earnestness and warmth. There was the same fire and the same exuberance of fancy which had enchanted me in his lectures thirty years before. At an age when most men hold speculation in small esteem, I was much struck with his criticism of a contemporary, who, he said, had no imagination, although he spoke with the highest praise of his experimental skill. At that time Dumas showed no signs of impaired strength. But during the following year his health began to fail, and he died on the 11th of April, at Cannes, where he had sought a retreat from the severity of the winter climate of Paris.

Dumas was one of the few men whose greatness cannot be estimated from a single point of veiw. He was not only eminent as an investigator of nature, but even more eminent as a teacher and an administrator. Beginning the study of chemistry at the culmination of the epoch of the Lavoisierian system, and regarding, as he always did, the author of that system with the greatest admiration, he nevertheless was the first to discover the weak point in its armor and inflict the wound which led to its overthrow. Without attempting to detail Dumas's numerous contributions to chemical knowledge, we will here only refer to three important investigations, which produced a marked influence in the progress of chemical science.

While still in Geneva, Dumas, as has been said, made numerous determinations of the densities of allied substances, with a view to discovering the relations of what he called their molecular or atomic volumes; and it is no wonder to us that the problem proved too complex to be solved at that time. After his removal to Paris he took up the much simpler problem which the relations of the molecular volumes of aeriform substances present, and his paper "On Some Points of the Atomic Theory," which was published in the *Annales de Chimie et de Physique* for 1826, had an important influence in developing our modern chemical philosophy. Gay-Lussac had previously observed, that not only the relative weights of the several factors and products concerned in a chemical process bear to each other definite proportions, but also, when the materials are aeriform, the relative volumes preserve an equally definite and still simpler ratio. Moreover, on the physical side, Avogadro, and afterwards Ampère, had conceived the theory, that in the state of gas all molecules must have the same volume. It was Dumas who first saw that these principles furnished an important means of verifying the molecular and atomic weights.

"I am engaged," he writes, "in a series of experiments intended to fix the atomic weights of a considerable number of

bodies, by determining their density in the state of gas or vapor. There remains in this case but one hypothesis to be made, which is accepted by all physicists. It consists in supposing that, in all elastic fluids observed under the same conditions, the molecules are placed at equal distances, i. e. that they are present in them in equal numbers. An immediate consequence of this mode of looking at the question has already been the subject of a learned discussion on the part of Ampère,"—and Avogadro as the author subsequently adds,—"to which, however, chemists, with the exception perhaps of M. Gay-Lussac, appear to have given as yet but little attention. It consists in the necessity of considering the molecules of the simplest gases as capable of a further division,—a division occurring in the moment of combination, and varying with the nature of the compound."

Here, it is obvious, are the very conceptions which form the basis of our modern chemical philosophy; and at first we are surprised that they did not lead Dumas at once to the full realization of the consequences which the doctrine of equal molecular volumes involves in the interpretation of the constitution of chemical compounds, and to the clear distinction between "the physical smallest particles" and "the chemically smallest particles," or the molecules and the atoms, as we now call the physical and the chemical units. This distinction is implied throughout Dumas's paper already quoted, and is illustrated by a striking example in the introduction to his treatise on "Chemistry applied to the Arts," published two years later; but the ground was not yet prepared to receive the seed, and more than a quarter of a century must pass before the full harvest of this fruitful hypothesis could be reaped.

There were, however, two important incidental results of this investigation from which chemical science immediately profited. One was a simple method of determining with accuracy the vapor densities of volatile substances which has since been known by Dumas's name. The other was a radical change in the formula of the silicates. On the authority of Berzelius, who based his opinion chiefly on the analogy between the silicates and the sulphates, the formula SiO_3 had been accepted as representing the constitution of silica. But from the density of both the chloride and the fluoride of silicon Dumas concluded that the formula was SiO_2, a conclusion which is now seen to be in complete harmony with the scheme of allied compounds. To Berzelius, however, the new views appeared wholly out of harmony with the system of chemistry which he had so greatly assisted in developing, and he opposed them with the whole weight of his powerful influence, and so far succeeded as to prevent their general adoption for many years.

Still, "the new mode of looking at the constitution of silicic acid slowly but surely gained ground, and it is now so firmly rooted in our convictions, that the younger generation of chemists will scarcely understand the pertinacity with which this innovation was resisted."*

But if this investigation of gas and vapor densities brought a great strain upon the dualistic system, the second of the three great investigations of Dumas, to which we have referred, led to its complete overthrow. The experimental results of this investigation would not be regarded at the present day as remarkable, and cannot be compared either in breadth or intricacy with the results of numerous investigations of a similar character which have since been made. The most important of these results were the substitution products obtained by the action of chlorine gas on acetic acid. They were published in a series of papers entitled "Sur les Types Chimiques," and the capital point made was that chlorine could be substituted in acetic acid for a large part of the hydrogen without destroying the acid relations of the products; and the inference was, that the qualities of a compound substance depend not simply on the nature of the elements of which it consists, but also on the manner or type according to which the elements are combined.

To the chemists of the present day these results and inferences seem so natural that it is difficult to understand the spirit with which they were received forty years ago. But it must be remembered that at that time the conceptions of chemists were wholly moulded in the dualistic system. It was thought that chemical action depended upon the antagonism between metals and metalloids, bases and acids, acid salts and basic salts, and that the qualities of the products resulted from the blending of such opposite virtues. That chlorine should unite with hydrogen was natural, for no two substances could be more unlike; but that chlorine should supply the place of hydrogen in a chemical compound was a conception which the dualists scouted as absurd. Even Liebig, the "father of Organic Chemistry," warmly controverted the interpretation which Dumas had given to the facts he had discovered. Liebig himself had successfully investigated the chemical relations of a similar class of organic products. He had, however, worked on the lines of the dualistic system, showing that organic substances might be classed with similar inorganic substances, if we assume that certain groups of atoms, which he called "compound radicals," might take the place of elementary substances. In the edition of the organic part of Turner's Chemistry bearing his name, Organic Chemistry is defined as the "Chemistry of Compound Radicals," and the formulæ of

* Hofmann, *loc. cit.*

organic compounds are represented on the dualistic system. Liebig's conceptions were therefore naturally opposed to those advanced by Dumas, but it is pleasant to know that the controversy which arose never disturbed the friendly relations between these two noble men of science, who could approach the same truth from different sides, and yet have faith that each was working for the same great end. In his commemorative address on Pelouze, Dumas expresses toward Liebig sentiments of affectionate regard, and Liebig dedicates to Dumas, with equal warmth, the German edition of his "Letters on Chemistry."

By the second investigation, as by the first, although Dumas gave a most fruitful conception to chemistry, he only took the first step in developing it. His conception of chemical types was very indefinite, and Laurent wrote of it, a few years later: "Dumas's theory is too general; by its poetic coloring, it lends itself to false interpretations; it is a programme of which we await the realization." Laurent himself helped towards this realization, and in his early death left the work to his associate and friend Gerhardt, who pushed it forward with great zeal, classifying chemical compounds according to the four types of hydrochloric acid, water, ammonia and marsh gas. Hofmann, Williamson, Wurtz, and many others, greatly aided in this work by realizing many of the possibilities which these types suggested; and thus modern Structural Chemistry gradually grew up, in which the types of Dumas and Gerhardt have been in their turn superseded by the larger views which the doctrine of quantivalence has opened out to the scientific imagination. It is a singular fact, however, that, while the growth began in France, the harvest has been chiefly reaped by Germans; and that, although in its inception the movement was strongly opposed in Germany, its legitimate conclusions are now repudiated by the most influential school of French chemists.

The third great investigation of Dumas was his revision of the atomic weights of many of the chemical elements, and in none of his work did he show greater experimental skill. His determination of the atomic weight of oxygen by the synthesis of water, and of that of carbon by the synthesis of carbonic dioxide, are models of quantitative experimental work. To this investigation, as to all his other work, Dumas was directed by his vivid scientific imagination. In his teaching, from the first, he had aimed to exhibit the relations of the elementary substances by classing them in groups of allied bodies; and at the meeting of the British Association in 1851 he had delighted the chemical section by the eloquence and force with which he exhibited such relations, especially triads of elementary substances; such as chlorine, bromine and iodine; oxygen, sulphur

and selenium; phosphorus, arsenic and antimony; calcium, barium and strontium; in which not only the atomic weight, but also the qualities of the middle member of the triad, were the mean of those of the other two members. Later, he came to regard these triads as parts of more extended series, in each of which the atomic weights increased from the first to the last element of the series, by determinate, but not always by equal differences, the values being, if not exact multiples of the hydrogen atom according to the hypothesis of Prout, at least multiples of one half or one quarter of that weight. There can be no doubt that these speculations were more fanciful than sound, and that Dumas did not do full justice to earlier theories of the same kind; but with him these speculations were merely the ornaments, not the substance of his work, and they led him to fix more accurately the constants of chemistry, and thus to lay a trustworthy foundation upon which the superstructure of science could safely be built.

That exuberance of fancy to which we have referred made Dumas one of the most successful of teachers, and one of the most fascinating of lecturers. It was the privilege of the writer to attend the larger part of two of his courses of lectures given in Paris in the winters of 1848 and 1851, and he remembers distinctly the impression produced. Besides the well-arranged material and the carefully prepared experiments, there was an elegance and pomp of circumstance which added greatly to the effect. The large theatre of the Sorbonne was filled to overflowing long before the hour. The lecturer always entered at the exact moment, in full evening dress, and held to the end of a two hours' lecture the unflagging attention of his audience. The manipulations were entirely left to the care of a number of assistants, who brought each experiment to a conclusion at the exact moment when the illustration was required. An elegance of diction, an appropriateness of illustration, and a beauty of exposition, which could not be excelled, were displayed throughout, and the enthusiasm of a French audience added to the animation of the scene.

To the writer the lectures of Dumas were brought in contrast to those of Faraday. Both were perfect of their kind, but very different. Faraday's method was far more simple and natural, and he excelled Dumas in bringing home to young minds abstruse truths by the logic of well arranged consecutive experiment. With Dumas there was no attempt to popularize science: he excelled in clearness and elegance of exposition. He exhausted the subject which he treated, and was able to throw a glow of interest around details which by most teachers would have been made dry and profitless.

Two volumes of Dumas's Lectures have been published;

one comprises his course on the Philosophy of Chemistry, delivered at the College of France in 1836; the other contains only a single lecture, accompanied by notes, entitled "The Balance of Organic Life," which was delivered at the Medical School of Paris, August 20, 1841. In both these volumes will be found the beauty of exposition and the elegance of diction of which we have spoken, and they are models of literary style. But of course the sympathetic enthusiasm of the great man's presence cannot be reproduced by written words.

The lecture on "The Balance of Organic Life" was probably the most remarkable of Dumas's literary efforts. It dealt simply with the relations that the vegetable sustains to the animal kingdom through the atmosphere, which, though now so familiar, were then not generally understood; and the late Dr. Jeffries Wyman, who heard the lecture, always spoke of it with the greatest enthusiasm.

As might be expected, Dumas's oratory found an ample field in the Chamber of Deputies and in the Senate; and whether setting forth a project of recasting the copper coinage or a law of drainage, or ridiculing the absurd theories of homeopathy, he riveted the attention of his colleagues as completely as he had entranced the students at the Sorbonne.

In the early part of his life, Dumas was a voluminous writer, and in 1828 published the "Traité de Chimie appliquée aux Arts," in eight large octavo volumes, with an atlas of plates in quarto. But besides this extended treatise, the two volumes of Lectures just referred to are his only important literary works. He published numerous papers in scientific journals, which, as we have seen, produced a most marked effect on the growth of chemical science. But the number of his monographs is not large compared with those of many of his contemporaries, and his work is to be judged by its importance and influence rather than by the extent of the field which it covers.

In his capacity of President of the Municipal Council at Paris, of Minister of Agriculture and Commerce, of Vice-President of the High Council of Education, and of Perpetual Secretary of the Academy of Sciences, Dumas had abundant opportunity for the exercise of his administrative ability, and no one has questioned his great powers in this direction; but in regard to his political career we could not expect the same unanimity of opinion. That he was a liberal under Louis Philippe, and a reactionist under Louis Napoleon, may possibly be reconciled with a fixed political faith and an unswerving aim for the public good; but his scheme for "civilian billetting" (by which wealthy people having rooms to spare in their houses would have been compelled to billet artisans employed in public works) leads one to infer that his statesmanship was not equal

to his science. Nevertheless, there can be no question about his large-hearted charity. He instituted the "Crédit Foncier," which flourishes in great prosperity to this day; he also founded the "Caisse de Rétraite pour la Vieillesse," and several other agricultural charities, which, though less successful, afford great assistance to aged workmen. Louis Napoleon used to say in jest that the whole of the War Minister's budget would not have been enough to realize M. Dumas's benevolent schemes; and once, half dazzled, half amused, by one of the chemist's vast sanitary projects, he called him the "the poet of hygiene."

It was to be expected that a man working with such eminent success in so many spheres of activity, and at one of the chief centers of the world's culture, should be loaded with medals, and marks of distinction of every kind. It would be idle to enumerate the orders of knighthood, or the learned societies, to which he belonged, for, so far from their honoring him, he honored them in accepting their membership. It is a pleasure, however, to remember that he lived to realize his highest ambitions and to enjoy the fruits of his well-earned renown. France has added his name in the Pantheon

"Aux Grands Hommes la Patrie Reconnaissante."

Art. XXXVIII.—*A New Meteorite;* by I. R. Eastman.

While staying over Sunday in the city of Grand Rapids, Mich., in September 1883, I saw in a local newspaper a reference to a strange, heavy, metallic mass which was to be seen in the store of Mr. C. G. Pulcher. Early Monday morning I found the store and immediately recognized the meteoric character of the mass.

It was roughly pear-shaped, 14 inches long and 9·6 inches in diameter at the thickest part, and weighed 114 lbs.

It was discovered about May 15, 1883, by Michael Clancy, a contractor, while making an excavation for building purposes on land belonging to the Catholic Church in Grand Rapids. It was found about three feet below the natural surface of the ground wedged between two large bowlders and was removed with considerable difficulty. The finder feeling certain that he had secured a valuable prize kept his secret for some weeks and expended much time and labor with hammer and cold chisel in the attempt to cut off the smaller end. He succeeded, however, only in mutilating the unusually fine specimen by cutting a groove about three-sixteenths of an inch deep quite around the mass and six inches from the smaller end.

Mr. Pulcher could not then be induced to part with the mass but I finally secured a few grains in weight, from the bur left by the chisel, from which Mr. F. W. Taylor of the Smithsonian Institution made a preliminary analysis with the following result:

Weight of specimen submitted to analysis 24 grains.

Analysis.

Iron	94·543
Nickel	3·815
Cobalt	0·396
Insoluble residue	0·118

The fragment was somewhat oxidized which accounts in part for the shortage. The entire specimen is now in the Smithsonian Institution for examination and analysis.

U. S. N. Observatory, August 26, 1884.

SCIENTIFIC INTELLIGENCE.

I. Scientific Associations.

1. *The British Association.*—The fifty-fourth meeting of the British Association, which opened in Montreal on the 27th of August and closed on the 3d of September, was a notable one in many respects. In the first place, it was the first meeting ever held beyond the limits of Great Britain; and it was not without many misgivings that the experiment was tried. Its success reflects great credit upon the management and must be gratifying to all concerned. Between 800 and 900 members crossed the Atlantic in order to be present; and the courtesy of temporary membership accorded to the Fellows of the American Association largely increased the number in attendance. Moreover, the number of persons who formally joined the Association at Montreal, either as members or as associates, was very large, having been stated as between 1400 and 1500.

In the next place, the addresses delivered were of exceptional excellence. After a few words of welcome from the Governor-General, Lord Lansdowne — in which he gracefully mentioned that the honor of knighthood had been conferred by the Queen upon Principal Dawson—Sir Wm. Thomson, acting for Professor Cayley, the President, introduced the incoming President, Lord Rayleigh. The subject of his address was "Recent progress in physics." Two quotations may be made from the concluding portion: "In speaking unfavorably of superfluous hypothesis," he says, "let me not be misunderstood. Science is nothing without generalizations. Detached and ill-assorted facts are only raw material, and in the absence of a theoretical solvent, have but little nutritive value. At the present time and in some depart-

ments the accumulation of material is so rapid that there is danger of indigestion. By a fiction as remarkable as any to be found in law, what has once been published, even though it be in the Russian language, is usually spoken of as 'known' and it is often forgotten that the rediscovery in the library may be a more difficult and uncertain process than the first discovery in the laboratory. . . . . If, as is sometimes supposed, science consisted in nothing but the laborious accumulation of facts, it would soon come to a standstill, crushed as it were under it own weight. The suggestion of a new idea, or the detection of a law, supersedes much that had previously been a burden on the memory, and by introducing order and coherence facilitates the retention of the remainder in an available form. . . . . Two processes are thus at work side by side, the reception of new material and the digestion and assimilation of the old. . . . . The work which deserves, but I am afraid does not always receive the most credit, is that in which discovery and explanation go hand in hand, in which not only are new facts presented but their relation to old ones pointed out." Again, referring to educational systems, Lord Rayleigh says: "From the general spread of a more scientific education we are warranted in expecting important results. Just as there are some brilliant literary men with an inability or at least a distaste practically amounting to inability for scientific ideas, so there are a few with scientific tastes whose imaginations are never touched by merely literary studies. To save these from intellectual stagnation during several important years of their lives is something gained; but the thorough going advocates of scientific education aim at much more. To them it appears strange and almost monstrous that the dead languages should hold the place they do in general education; and it can hardly be denied that their supremacy is the result of routine rather than of argument. . . . . It is useless to discuss the question upon the supposition that the majority of boys attain either to a knowledge of the languages or to an appreciation of the writings of the ancient authors. The contrary is notoriously the truth; and the defenders of the existing system usually take their stand upon the excellence of its discipline. From this point of view there is something to be said. The laziest boy must exert himself a little in puzzling out a sentence with grammar and dictionary, while instruction and supervision are easy to organize and not too costly. But when the case is stated plainly few will agree that we can afford so entirely to disregard results. . . . . I believe that French and German if properly taught, which I admit they rarely are at present, would go far to replace Latin and Greek from a disciplinary point of view, while the actual value of the acquisition would in the majority of cases be incomparably greater. In half the time usually devoted without success to the classical languages, most boys could acquire a really serviceable knowledge of French and German."

Professor Sir Wm. Thomson, President of the Physical Section

entitled his address, "Steps toward a kinetic theory of matter," discussing in it, in his masterly and suggestive way, the manner in which the properties of matter, especially elasticity, may be accounted for on the kinetic theory. Sir Henry E. Roscoe, as President of the Chemical Section, reviewed with great ability the progress of chemical theory, from the death of Berzelius, in 1848, to the present, and closed with a valuable discussion of the physical questions now pressing on the chemist. Mr. W. T. Blanford addressed the Geological Section on the "Correlations of geological formations;" Professor Moseley the Biological Section, on "The physiology of deep-sea life;" General Sir J. H. Lefroy, the Geographical Section, on "Recent geographical discovery;" Sir Richard Temple, the Section of Economic Science and Statistics, on "The general statistics of the British Empire;" Sir Fredk. J. Bramwell, the Mechanical Section, on "The relation of mechanical science to other sciences," and Dr. E. B. Tylor, the Anthropological Section, on "Some American aspects of anthropology."

Again, the character of the papers presented was in general of a high order. Among the most important of those read in the Physical Section may be mentioned those by Lord Rayleigh, "A lecture experiment on induction," "On telephoning through a cable," "On a galvanometer with twenty wires," "On the colors of thin plates," and "On Clark's standard cells;" by Sir Wm. Thomson, "On a gyrostatic working model of the magnetic compass," and "On safety fuses for electric circuits;" by Professor Dewar, on "The law of total radiation at high temperatures;" by J. T. Bottomley, "On loss of heat by radiation and convection as affected by dimensions of the cooling body and on cooling in a vacuum;" by Professor Shuster, "On the influence of magnetism on the discharge of electricity through gases;" by Professor Fitzgerald, "On an analogy between heat and electricity;" by Professor Rowland, on "Recent progress in photographing the solar spectrum," and Rev. S. J. Perry, "On the spot-spectrum from D to B;" by Professor Chandler Roberts, "On the diffusion of metals;" by Professor Michelson, on "The velocity of light in carbon disulphide and the difference of the velocities of red and blue light in the same;" by W. H. Preece, "On the law regulating the connection between current and intensity of incandescence of carbon filaments in glow lamps;" and by Professor S. P. Thompson, on "The equations of dynamo-electric machines."

Among the papers of note in the Chemical Section were those by Dr. Wolcott Gibbs, "On complex inorganic acids;" by Sir Henry Roscoe, "On the diamondiferous deposits of South Africa;" by Professors Liveing and Dewar, "Spectroscopic studies of explosions;" by Professor Dewar, "On the liquefaction of oxygen and on the density of liquid hydrogen;" by Mr. H. B Dixon, "Experiments on gaseous combustion," and "On the velocity of explosions in gases;" by Dr. W. H. Perkin, "On

the magnetic rotation of compounds in relation to their chemical composition," and "On coal-tar coloring matters;" by Dr. J. H. Gladstone, "On the present state of our knowledge of refraction equivalents;" by Professor Frankland, "On the chemical aspect of the storage of energy;" and by Professor Tilden, "On some phenomena of solution."

Two excellent features of the sectional work should be noted. The first is the discussion of fundamental questions. In the Physical Section, the subjects discussed were: "The seat of the electromotive forces in the voltaic cell," the discussion being opened by Professor O. J. Lodge, who took ground against the contact theory; and "The connexion of sun-spots with terrestrial phenomena," opened by Professor A. Shuster. In the Chemical Section Professor Dewar opened the discussion "On the constitution of the elements" and Professor Frankland the discussion "On chemical changes in their relation to micro-organisms." The second feature is the special reports presented to the sections. The Physical Section received the reports of Committees on electric standards, on the harmonic analysis of tidal observations, on tidal observations in the English Channel, on the measurement of solar radiation, on meteoric dust, and on facilitating the adoption of the metric system in Great Britain. Reports of Committees to the Chemical Section were made by Professor Chandler Roberts "On spectrum analysis;" and by Mr. H. B. Dixon on "Chemical nomenclature."

Nor was the social element forgotten at the Montreal meeting. The transatlantic members were treated most liberally by the government railroads, especially the Canadian Pacific, which granted them free transportation to its western terminus. On Saturday, the 30th, excursions were made to Quebec, to Ottawa, and to Lake Memphremagog. And at the close of the meeting a select party of 150 was taken to the Rocky Mountains and another of 300 to Toronto, by the Canadian Pacific. Private hospitality was offered abundantly; and dinners, receptions and lawn parties were numerous. The weather was delightful and the social success of the meeting was equal to the scientific one. G. F. B.

2. *The American Association.*—The Philadelphia meeting of the American Association may justly be put on record as the largest and most successful in its history. Whether measured by the number of members in attendance, which reached the unprecedented figure of 1249, by the number of added members, given as 491, by the number of papers presented, 345 as recorded on the Secretary's list, on the one hand; or by the quality of the meeting, the unusual number of eminent men present, both from this country and Europe, and the high character of the papers presented, on the other; the general verdict seems to be unanimous in placing this meeting as exceptionally large and interesting.

The meeting opened on Thursday morning, Sept. 4th, in the Academy of Music, Professor Young resigning the Presidency to

Professor Lesley, and speeches of welcome being delivered by Governor Pattison and Mayor Smith. In the afternoon, the Vice Presidents delivered their addresses to the respective sections. Professor Eddy, in Section A, took for his subject "The present state of mathematical training in our colleges; its aims, its needs and its relations to education and to scientific research." To Section B, Professor Trowbridge discoursed upon "What is Electricity," hoping thereby to make his audience ask themselves the question with more humility and a greater consciousness of ignorance. "We shall probably never know," he says "what electricity is, any more than we shall know what energy is. What we shall be able, probably, to discover, is the relationship between electricity, magnetism, light, heat, gravitation and the attracting force which manifests itself in chemical changes." Professor J. W. Langley, in addressing Section C, took "Chemical Affinity" as his subject, considering the thermal, the electrical, and the time methods of studying it. Professor Thurston spoke to Section D on "The mission of science;" Professor Winchell to Section E on "The crystalline rocks of the northwest;" Professor Cope to Section F on "Catagenesis, or creation by retrograde metamorphosis of energy;" Professor Morse to Section H on "Man in the Tertiaries;" and Gen. John Eaton to Section I on "Scientific methods and scientific knowledge in common affairs."

The address of the retiring President, Professor Young, was delivered in the Academy of Music on Friday evening. He selected as his subject "Some of the pending problems in astronomy," discussing, in his clear, thoughtful and able way, those questions, in the first place, "which seem to be most pressing and which most urgently require solution as a condition of advance;" and, in the second, "which appear in themselves most interesting or likely to be fruitful from a philosophic point of view." The first to be considered were, "the questions which relate to the dimensions and figure of the earth, the uniformity of its diurnal rotation and the constancy of its poles and axis." The earth's dimensions are so uncertain as to produce serious embarassment in the reduction and comparison of certain lunar observations. "As to the form of the earth" he says, "it seems pretty evident that before long it will be wise to give up further attempts to determine exactly what spheroid or ellipsoid most nearly corresponds to the actual figure of the earth. . . . It will be better to assume some closely approximate spheroid as a finality; its elements to be forever retained unchanged, while the deviations of the actual surface from this ideal standard will be the subject of continued investigation and measurement." As to the uniformity of the earth's rotation, Professor Young says, "The time must unquestionably come when the accuracy of scientific observation will be so far increased, that the irregularities of the earth's rotation, produced by the causes alluded to a few minutes ago, will protrude and become intolerable. Then a new unit of time will have to be found for scientific purposes, founded

perhaps, as has been already suggested by many physicists, upon the vibrations or motion of light or upon some other physical action which pervades the universe." The address passes next to the moon and considers the unsatisfactory condition of the lunar theory; to the planets and discusses the accordance of theory with observation in their motions, expressing the opinion that "the tremendous array of negative evidence from the most trustworthy observers, with the best equipment and opportunity, makes it little short of certain that there is no Vulcan in the planetary system;" to the sun itself, giving a masterly statement of the difficulties yet unconquered in the theory of his constitution; to comets, "those strange objects of such enormous volume and inconceivable tenuity, self-luminous and transparent, yet reflecting light, the seat of forces and phenomena unparalleled in all our other experience;" and finally to the problems of stellar astronomy; closing with a few well chosen words upon the advantages of the study of truth for its own sake, since "in the investigation and discovery of the secrets and mysteries of the heavens the human intellect finds most invigorating exercise and most nourishing and growth-making aliment."

Of the papers read, it will, of course, be impossible to speak in detail. Those communicated to Section A numbered 37, those to Section B 42, and those to Section C 29. Among the physical papers, those of Professor Mendenhall "On the variation of the resistance of carbon under pressure;" of Professor W. A. Rogers "Additional observations confirming the relation: Metre des Archives = Imperial yard + 3·37027 inches;" by Professor W. H. Pickering "Photography of the infra-red region of the spectrum;" of Professor Carhart "Relation of the electromotive force of a Daniell cell and the strength of the zinc sulphate solution;" of Dr. W. Thomson "Method for the practical examination of railway employees as to color blindness, acuteness of vision and hearing; with the results obtained by it on the Pennsylvania railroad;" of Professor Harrington "Notes on Aneroids;" of Professor Graham Bell "On a possible method of electrical communication between vessels at sea;" of Professor E. H. Hall "On the magnetic rotation of the equipotential lines of electric currents in various metals and alloys;" of Professor Wead "On the intensity of sound, and the energy used by an organ pipe," may be mentioned. Among the other papers of interest read in the section of chemistry, those of Dr. Springer on "Torsion balances;" of Professor Wiley "Optical methods of estimating sugar in milk;" of Professor Atwater "On the assimilation of atmospheric nitrogen by plants;" of Professor Langley "An explanation of Gladstone and Tribe's 2–3 law in chemical dynamics;" and of Miss Abbott "Preliminary analysis of the bark of *Fouquieria splendens* Engl." may be specified.

The number of members of the British Association present at Philadelphia was gratifyingly large. A special train from Montreal to Philadelphia on Thursday brought about 200; and more

than a hundred came by other routes. They were made honorary members of the American Association, and many of them took an active part in the work of the sections. Among the papers thus presented may be mentioned those by Professor Sir Wm. Thomson "On the distribution of potential in conductors experiencing the electromagnetic effects discovered by Hall;" by Professor James Dewar on "Electric discharges in relation to the equilibrium of gaseous atmospheres" and "The density of solid carbonic acid;" by Professor J. C. Adams "On the general expression for the value of the obliquity of the ecliptic at any given time, taking into account terms of the second order," and "Note on Newton's theory of atmospheric refraction and on his method of finding the motion of the moon's apogee;" by Professor A. Vernon Harcourt "On the minute study of chemical change" and "On a lamp for producing a constant flame;" by Sir Frederick Bramwell on "Heating from a central source;" by Rev. S. J. Perry, on "Late researches on the solar surface with special reference to evanescent spots;" by Professor Robert S. Ball, exhibiting and describing a model of the "ruled cubic surface known as the cylindroid;" by Professor H. N. Moseley "On the presence of eyes and other sense organs on the shells of Chitonidæ," "Utricularia vulgaris with young teleostean fishes entrapped in the bladder-trap of that plant" and "On the feathers of the Dodo;" by Dr. E. B. Tylor "Remarks on North American races and civilization;" by Professor J. G. McKendrick "On ethidene dichloride as an anæsthetic." Papers were read also by Capt. Bedford Pim, J. Biddulph Martin, Professors W. F. Barrett, S. P. Thompson, H. Hennessey, Valentine Ball and A. H. Allen, and Mr. Trelawney Saunders.

The introduction of subjects for discussion by the sections constituted a new and valuable feature of the meeting. Through the efforts of Professor J. W. Langley, its Vice President, Section C had three discussions. The first was on "Valence," and was opened by Professor F. W. Clarke; the second was on "Fermentation," and was opened by Dr. Alfred Springer; the third was on "Educational methods in laboratory practice and in the illustration of chemical lectures," opened by Professor Remsen. Section D discussed on Monday, "The use and value of accurate standards, screws, surfaces, gauges, etc.;" and on Wednesday, "The applications of electricity."

Lectures were delivered at the Academy of Music on Thursday evening by Professor J. S. Newberry of New York on "The geological evolution of the North American continent," and on Tuesday evening by Professor Robert Stawell Ball, Astronomer Royal for Ireland, on "Recent researches on the distances of the stars." Both lectures were illustrated with the lantern.

The social festivities of the meeting were given on a magnificent scale. On Friday evening, before Professor Young's address, the American Association was welcomed by President Welsh of the Local Committee, and the British Association by Provost Pepper

of the University of Pennsylvania on behalf of the citizens of Philadelphia. After the address the Academy of Music was thrown open for a grand promenade concert and reception for the remainder of the evening. On Tuesday evening the Local Committee gave a brilliant reception at the Academy of Fine Arts, and on Wednesday afternoon the Ladies' Reception Committee gave a charming Lawn Party on the grounds of Haverford College. On Monday afternoon receptions were given by the Local Committee, Trustees and Faculty at the University of Pennsylvania, by the Women's Medical College, by the Zoological Gardens to witness Mr. Muybridge's instantaneous photographic work, and by the Botanical section of the Academy of Natural Sciences.

The excursions, moreover, were on an exceedingly liberal scale. The Pennsylvania railroad gave three excursions to the seashore, viz: to Long Branch, to Cape May and to Atlantic City. The Philadelphia & Reading railroad gave an excursion to the anthracite coal regions. All of these were well patronized, especially the latter, which numbered about 400, including some members of the American Institute of Mining Engineers. Under the excellent guidance of Mr. Ashburner, of the State Geological Survey, the day was most pleasantly spent. Other minor excursions were organized to inspect the local geology and the local botany of Philadelphia.

The city of William Penn has fully sustained the reputation for bounteous hospitality which it acquired a century ago and has ever since maintained. Unfortunately the heat during the meeting was intense, and made a burden of many a pleasure. But in spite of the high temperature, the second meeting of the American Association at Philadelphia will ever remain a bright and pleasant memory.

G. F. B.

II. Physics.

1. *Papers read before the Physical Section at the meeting of the American Association for the Advancement of Science at Philadelphia.*—The papers read before the Physical section of the American Association for the Advancement of Science at the Philadelphia meeting have covered a varied field. The growing interest in and importance of photography were shown by papers from Mr. W. H. Pickering on the use of dry plates in photographing the infra red, in which he showed that it was comparatively easy to photograph far into this region by such plates. A discussion upon this subject was carried on in which Professor Rowland stated his opinion that time was an important element in such work. Professor Abney by his emulsions could obtain photographs in ten minutes. Professor Rowland spoke of his experience in photographing the solar spectrum with his new gratings, and expressed his conviction that special emulsions must be prepared for the work and that reliance could not be placed upon dry plates obtained from the manufacturers for

work in the infra red. Mr. Hough described a new form of Sensitometer for use in photography. Mr. Nichols read a paper on a Spectrophotometer for studying the intensity of light reflected from various pigments and gave a method by means of which the observations could be reduced to absolute measure. The instrument consisted of a spectroscope provided with a Nicols prism and a totally reflecting prism. The intensity of the spectrum could be reduced known amounts by the Nicols prism, and the reflecting prism allowed the light reflected from the pigment to be compared with the proper portion of the solar spectrum. Mr. Nichols stated that he had found that the eyes of men in general were more sensitive to shades of color than those of women. Professor Carhart read the results of observations made in the Physical Laboratory of Berlin on the electromotive force of a Daniell cell with sulphate of zinc of varying density. His results show that this cell under certain conditions is very constant and can serve as a practical measure of electromotive forces in general. Mr. Hazen, of the United States Signal Service, gave a description of a proposed statistical method of studying the frequency and character of thunder storms, and showed the probability of a connection between the path of these storms and the regions of low barometric pressure. Professor Abbe of the Signal Service, in remarks upon this paper, commended in general the kind of work undertaken by Mr. Hazen. It was recommended by Professor Abbe that the name of the section should be so changed as to include the discussion of papers on terrestrial physics. This change was referred to the Standing Committee of the Association. A temporary subsection of section B was then formed, before which Professor Abbe presented various papers on seismology and the systematization of observation of temperature and electricity. The most noteworthy discussion that occurred was on the Hall Phenomenon. Mr. E. H. Hall read a paper on this subject, in which he referred to certain explanations of the phenomenon given by Mr. Shelford Bidwell, of Great Britain, and showed that they were not well grounded. Professor Sylvanus P. Thompson defended Mr. Bidwell and also described certain experiments of his own which he thought conclusively showed that it had not been proved by Mr. Hall that there is an electromotive force acting in a magnetic field at right angles to the direction of an electrical current passing through such a field. Sir William Thomson then took the floor and showed that the theory of electromagnetism demanded an effect of the nature discovered by Mr. Hall, and also said that many years ago he discovered certain equations in which the Hall phenomena "*lurked*," and he regarded Mr. Hall's paper as the most important contribution to the subject of magnetism which had appeared for many years. Sir William Thomson then gave a mechanical representation of the phenomenon. A paper by Mr. Loudon on the theory of thick lenses contained some interesting geometrical constructions.

J. T.

2. *Magnetic Polarity and Neutrality;* by Professor D. E. HUGHES, F.R.S.—The following paragraphs are from the beginning and close of a paper by Professor D. E. Hughes in the Proceedings of the Royal Society, No. 231:

"In recent papers upon the Theory of Magnetism,* I gave the opinion drawn from a long series of personal researches, that magnetism in iron and steel is entirely due to the inherent polarity of its molecules, the force of which could neither be destroyed nor augmented; that, when we have evident magnetism, the molecules rotate so as to have all their similar polarities in one direction; and that neutrality is a symmetrical arrangement or a balancing of polar forces, as in a closed circuit of mutual attractions. The series of researches which I now present bear unmistakable testimony to the truth of these views, showing the opposite polarities which exist in an apparently neutral bar of iron; and that it is by this means alone that external neutrality occurs in the iron cores of an electro-magnet upon the cessation of the inducing current. * * *

"That inherent magnetic polarity is a quality of all matter, solid, liquid, gaseous, and the ether itself, varying only in degree and not in nature, seems demonstrated by a series of researches I have been making upon the mechanism employed in magnetic conduction through the atmosphere and Crookes's vacuum.

"These researches are being made by means of the induction and magnetic balance. They prove that the atmosphere, and presumably the ether as well as all liquids and gases, have their saturation point similar to iron, that the curve is the same as in perfect soft iron, and that the highest magnetic capacity of iron does not exceed that of the atmosphere by more than forty times; consequently we may fairly assume that the ether may be regarded as an extremely magnetic body, obeying the same laws as those of iron; and as I regard the symmetrical rotation of magnetic molecules as the cause of evident magnetism in iron, and as the difference in force between iron, copper and ether is simply a differential one, I believe that the neutrality which appears in all paramagnetic and diamagnetic bodies, wherever the exciting influence is withdrawn, is formed by mutual molecular reactions producing closed circuits of mutual attractions as demonstrated in iron.

"A line of force between a magnet and its armature is to me simply a line of molecular rotation; lines would neither be added nor subtracted; they could simply be rotated from a symmetrical neutrality to an equal symmetrical point of saturation.

"In my paper upon the theory of magnetism, I showed that there were several molecular arrangements which produced external neutrality—the circular chain of molecules, when an electric current passes through an iron wire, a neutrality produced by an artificial superposition of a weaker contrary magnetism

* "Proc. Roy. Soc." (vol. 35, p. 178) and "Journal of the Society of Telegraph Engineers," vol. xii, 1883.

upon one more internal—and made the supposition that were it possible to have a piece of iron free from the influence of the earth, then (if there had been no previous magnetization directing the structure) the molecules would short circuit their mutual attractions in the shortest path.

"The experiments cited in this paper are of an extremely simple nature, and after being verified by independent observers can no longer leave doubt as to the cause of neutrality.

"Whatever theory we adopt as an explanation of evident magnetism, it will be found that neutrality occurring after the cessation of an external inducing force upon a bar of iron or steel is the result of symmetrically opposed polar forces, producing apparent waves of opposite polarity, or reactions between the exterior and interior of a bar of iron."

3. *Report on the International Exhibition of Electricity held at Paris, August to November*, 1881; by Major DAVID PORTER HEAP, Corps of Engineers, U. S. A. 287 pp. 8vo. Washington, 1884 (Engineer Department, U. S. A.).—This volume contains brief descriptions of many of the electrical arrangements exhibited at the Paris Exhibition; these include many forms of batteries, dynamo and magneto electric machines, electro-motors, electric lamps, light houses and so on. The value of the descriptions given is increased by the fact that they are profusely illustrated. This publication has additional interest at the present moment in view of the similar exhibition now being held at Philadelphia.

4. *The Modern High Explosives.* Nitro-glycerine and Dynamite: their manufacture, their use and their application to mining and military engineering; Pyroxyline or Gun-cotton; the Fulminates, Picrates and Chlorates; also the chemistry and analysis of the elementary bodies which enter into the manufacture of the principal nitro-compounds; by MANUEL EISSLER, Mining Engineer. 395 pp. 8vo. New York, 1884 (John Wiley & Sons).—The title to this work, which has been quoted in full, is so comprehensive as to give a fair impression of its scope and value. In the treatment of the subject, it is divided into three parts; the first is devoted to the chemistry and analysis of the substances from which the high explosives are manufactured and the description of these explosives themselves; the second gives directions for the use of the high explosives, describing also the use of electricity in blasting operations; and the third gives the principles of blasting, the force and effect of explosive bodies, and many practical points bearing on mining and engineering problems, the explosions of mines, the destruction of walls, various obstructions as in navigation or in agriculture, and so on. The volume contains a large amount of useful information much needed in view of the constantly increasing use of high explosives, and the often comparative ignorance of those who handle them.

5. *Light;* by P. G. TAIT, M.A., etc. 276 pp. 12mo. Edinburgh, 1884 (Adam and Charles Black).—Professor Tait's excellent little treatise on Heat, noticed in a recent number of this

Journal (xxvii, 488) is now followed by a no less valuable companion volume on Light. This volume is the more welcome since contributions to the department of physics of which it treats, of a general nature, have been few in recent years, while there are numerous excellent volumes upon heat and electricity, adapted to the needs of all grades of students. This volume is elementary in character, and is especially suited to the private reading of a student to supplement the instruction of the class-room. It is fresh in matter and clear in style. A valuable feature, and one which is of necessity absent in class-room text-books, is to be found in the attention given to the historical development of the subject; numerous quotations from Newton, La Place, Huyghens and others are calculated to make clear to the student how the present accepted principles and theories have been reached.

III. Geology and Natural History.

1. *Professor James Hall on the "Hudson River" age of the Taconic slates.*—At the meetings of the American Association of Geologists and Naturalists (the antecedent of the present American Association) 40 to 45 years since, the age of the Taconic system was the subject of long discussions; and in the course of them Professor Hall advocated, in opposition to Professor Emmons, the Lower Silurian age of the Taconic slates and limestones, citing facts in proof from his own investigations. No paper on the subject was published by him, and not even a report of the discussions of the Association.

In connection with a recent letter, dated Albany, September 13, the writer has received from Professor Hall copies of two plates of sections prepared by him as early, he states, as 1845, exhibiting—as the result of his own studies—the positions of the rocks along four lines; one from Petersburgh, New York, eastward through the Taconic of Williamstown and Adams, Massachusetts; the *second*, 10 miles north of the first, through Hoosick and Mt. Anthony in the Taconic Range in Bennington; a *third* through Arlington and Equinox Mountain of the Taconic Range of Vermont; and a *fourth* still farther north, through Castleton and Rutland, Vermont. In the first-mentioned the limestone is made to underlie conformably, in a synclinal, the Taconic schists of Saddle Mountain and Graylock (as also shown by Emmons); in the *second*, Mt. Anthony is proved to be a broad synclinal of slates with limestone beneath; and in the third, Equinox Mountain is another synclinal of slate with underlying limestone—thus long anticipating in the exhibition of these broad synclinals, the similar sections of the Vermont Geological Report (1862). Underneath each section the limestone is stated to be of the age of the "Trenton and lower" formations, and the Taconic slates are made, as necessarily follows from the position of the limestone, of later Lower Silurian or the Hudson River group. The slates at Hoosick River had been previously proved to afford

graptolites; and hence the limestone adjoining them and conformable in bedding with them was reasonably referred to the Lower Silurian. He writes that as to the precise period of the Hoosic slates, then made "Hudson River," he is at present uncertain.

At the Montreal meeting of the British Association Professor Hall expressed his belief in the synclinal character of Mt. Washington—the subject of the writer's paper at page 268 of this volume, and in the general synclinal character of the Taconic Range. J. D. D.

2. *Earthquakes of Ischia.*—The facts connected with the earthquakes of Ischia, from 1828 to 1883, and the theories brought forward in explanation, are discussed by Dr. Francis DuBois, in a paper published in vol. vii of the Transactions of the Seismological Society of Japan (p. 16, read Dec. 20, 1883). The following resumé of the facts and conclusions make the close of the paper:

Resumé.—What then do we really know about the Ischian earthquakes? Whatever is admitted by all or denied by none may be accepted as true.

All Ischian earthquakes of which any special record has been made resemble each other, in fact are a counterpart of one another, differing only in intensity, having a special type of which the following are the common and constant characteristics:

(1) If there are any premonitory signs one never hears of them until after the earthquake has taken place. There are always prophets after an event.

(2) Great suddenness; there is but one serious shock and all is over. Succeeding earthquakes are of very little importance.

(3) Extreme localization. There is not a gradually diminishing intensity of the seismic wave as it recedes from the seismic center, but the area of damage is clearly marked.

(4) The cause of the earthquake whatever it may be, whether it be a fissure, or the formation of a volcanic rent, or a subterranean falling in, or explosion, or what not, is comparatively near the surface.

(5) There are no evident volcanic phenomena accompanying the earthquake.

(6) If the seismic wave is felt outside of the island at all it is felt very slightly.

(7) There is no disturbance of the sea.

(8) Three days after the earthquake of 1881 there was not the least vibration of the soil discernible even with a microphone. Strange to say no notice one way or the other has reached me with regard to the earthquake of 1883.

Conclusions.—(1) That it is very much to be regretted that after the disaster of 1881 no efficient measures were taken to investigate the physical phenomena of the island of Ischia.

(2) That it is very difficult to arrive at any positive conclusion from reading the different reports. On doing so, one has an intimate feeling that every one goes there with a pre-conceived theory and only hunts out facts to corroborate it.

(3) The fact of the earthquake not having been sensibly felt in Naples or on the adjoining shore should not influence our judgment much either way, for in 1857 Capri scarcely felt the shock which was very severe in the promontory of Sorrento. Now the promontory and the island belong to the same geological formation and are very near each other.

On the other hand the motion noticed by Professor Rossi in his instruments at Rome, and the various phenomena he mentions in connection with the Ischian earthquake, as happening at that time near Rome, are not by any means necessarily connected with the Ischian earthquake.

Although in all Ischian earthquakes some commotion on the continent has been noticed, this commotion has invariably taken place at a very considerable distance, while in the immediate neighborhood no motion was perceptible. It is very problematical whether these distant motions are anything but a coincidence.

(4) When one thinks of the enormous amount of lava which has been ejected from the many cones on the island one can understand that there may be enormous cavities below the soil.

When we consider the corroding influence of carbonic acid and water: and the great number of hot springs and the quantity of water they are continually pouring forth and have been pouring forth since time immemorial, that cavities may exist becomes still more evident.

If besides this, we remember that sufficient clay is being continually taken out of the soil to furnish bricks, tiles and cooking utensils not only for the island itself but for all the neighboring mainland; that this clay is not on the surface but is all taken from excavations and galleries, mined as it were; that this process is by no means a new one but has been going on for generations; we see then causes tending still further to honeycomb the soil. The soil therefore being cavernous, a sudden collapse is not only possible but probable, and we can understand that it might produce remarkable effects.

(5) The great suddenness and localization of the Ischian earthquake, together with the absence of any volcanic phenomena, should induce us to seek some other cause for the earthquake than a volcanic one; and as we have a set of conditions in the nature of the ground itself amply sufficient to account for most of the phenomena, we are justified, in the absence of further evidence, in considering this as an efficient cause. Whether the accidental cause was a fissure, a seismic wave, or an explosion or what not, is a consideration which only a lengthened and methodical observation in the future will enable us to find out.

3. *The Azoic System and its proposed Subdivisions;* by J. D. Whitney and M. E. Wadsworth. pp. 331–566, of vol. vii of Bulletin of the Mus. Comp. Zool. Cambridge, August, 1884.—The Azoic system—or Archæan, as it is now commonly called—was early made the subject of investigations by Professor J. D. Whitney and now finds in him a valuable exponent. The litera-

ture of the "Azoic" and the opinions of the various investigators in "Azoic" regions or writers on "azoic" questions are here reviewed by the authors, by means of a free use of citations and full explanations, accompanied and followed by critical remarks. The criticisms are largely just, though often expressed with a positiveness not altogether consistent with the uncertainties about such questions. Of course, as with other writers, they are in part determined by the special opinions of the authors, and are reasonable subjects for counter-discussion. The work is a valuable addition to the history of American geological science; and will be increasingly valued as the discussion of the subject proceeds.

Among the conclusions set forth, that as to the *azoic* condition of the "Azoic" era seems to be quite too doubtful to be accepted without a question. It is true that the supposed evidences of life in the late Archæan stratified rocks are doubtful; that the Eozoon is still among problematical things; that the limestones of the Archæan contain no fossils, so far as is positively known; but at the same time it is true that the "Azoic" is not yet proved to have been azoic,—is not yet proved to have *probably* been azoic; it is also true that the Archæan limestones have not been proved to be of chemical origin, or to be not of organic origin. The evidences on both sides are still doubtful evidences; and being so, it is impossible for most minds to settle down into the positive belief that the era was to the end without life or that the existence of life then was improbable; and hence the adoption of the non-committal term *Archæan* for the rocks and events of time preceding the Primordial—agreeing in limits as far as its proposer, the writer, understands (notwithstanding some remarks in the volume) with Whitney's Azoic.

The subdivisions of the Archæan are considered in the volume at much length and shown to be—even that of the Huronian—without a satisfactory basis. J. D. D.

4. *Thirteenth annual report on the Geology and Natural History of Indiana;* by JOHN COLLETT, State Geologist. 161 and 264 pp. 8vo, with many plates and a geological map. Indianapolis, 1884.—Besides a general review of the geology of the State and chapters on the local geology of some of its counties, this report contains tabular results of experiments on the heating value of Indiana coals, and about 180 pages on a review of its paleontology—including both vegetable and animal species. This paleontological part of the report is illustrated by 39 plates, more than half of which are plates of fossil plants. The botanical portion is by the able author on the subject, Leo Lesquereux, and includes an introduction on the formation of coal and other points of general interest. Mr. Lesquereux derives from the number of species of coal plants found in the nodules of the shale at Mazon Creek, Illinois and from the same shale elsewhere, that at least 200 species of plants contributed to the formation of a single bed of coal; and adding other species from the same horizon, the number

becomes 250. The review of the fossil invertebrates is by the well-known paleontologist Dr. C. A. White.

Mr. Collett has increased much the value of the volume by the insertion of a colored geological map of the State, compiled from the labors of the former State Geologist, Mr. Cox, and those of other workers in Indiana geology.

5. *Fossils as a criterion of Geological equivalency.*—The uncertainties connected with the use of fossils as a criterion of geological age was the subject of the able address before the geological section of the British Association at Montreal by its president, Mr. W. T. BLANFORD, formerly deputy superintendent of the Geological Survey of India. After reviewing the facts, and pointing out the diversity of opinions as to age, connected with the Tertiary Mammalian deposits of Pikermi, Greece, of Siwalik in the northwestern Himalaya, and of Sind; those pertaining to the fossils, chiefly plants, of the Gondwána system of India, and those of the coal-measures of Australia and the Karoo beds of South Africa, Mr. Blanford states objections to the commonly received view with regard to the approximate universality of faunas, floras and climates in ancient time, and concludes with the following recapitulation.

(1) That the geological age assigned on homotaxial grounds to the Pikermi and Siwalik mammalian faunas is inconsistent with the evidence afforded by the associated marine deposits.

(2) The age similarly assigned on the same data to the different series of the Gondwána system of India is a mass of contradictions; beds with a Triassic fauna overlying others with Rhætic or Jurassic floras.

(3) The geological position assigned on similar evidence to certain Australian beds is equally contradictory, a Jurassic flora being of the same age as a Carboniferous marine fauna.

(4) The same is probably the case with the terrestrial and fresh-water faunas and floras of South Africa.

(5) In instances of conflicting evidence between terrestrial or fresh-water faunas and floras on one side, and marine faunas on the other, the geological age indicated by the latter is probably correct, because the contradictions which prevail between the evidence afforded by successive terrestrial and fresh-water beds are unknown in marine deposits; because the succession of terrestrial animals and plants in time has been different from the succession of marine life; and because in all past times the differences between the faunas and floras of distant lands have probably been, as they now are, vastly greater than the differences between the animals and plants inhabiting the different seas and oceans.

(6) The geological age attributed to fossil terrestrial faunas and floras in distant countries on account of the relations of such faunas and floras to those found in European beds has proved erroneous in so large a number of cases that no similar determinations should be accepted unless accompanied by evidence from marine beds. It is probable in many cases—perhaps in the

majority—where the age of beds has been determined solely by the comparison of land or fresh-water animals or plants with those found in distant parts of the globe, that such determinations are incorrect.

6. *The Geology of Minnesota*, vol. I of the Final Report; by N. H. WINCHELL, assisted by WARREN UPHAM. 698 pp. 4to, with 43 plates.—This large and handsome volume commences with an excellent historical sketch of explorations in Northwestern America, from early in the 17th century to the present time, which is illustrated by reproductions of several old maps of North America (or of parts including Minnesota)—those by Hennepin (1683), Franquelin (1688), De L'Isle (1703), De Beauharnois (1737), Buache (1754); and that of Nicollet, of 1842, the result of an important topographical survey. The physical features of Minnesota are next described by Professor Winchell; the building stones, by the same; and then follow chapters on the geology of twenty-eight counties by Mr. Winchell and Mr. Upham, excepting that two of them are by Mr. M. W. Harrington. Of the 84,286 of square miles in the State, the lakes make up 5,637 square miles; and nearly all the rest is under drift—the "only exceptions being the extreme southeastern and the extreme northeastern portions" and some scattered outcrops elsewhere; and this drift in the southern half of the State is an almost unbroken mantle from 100 to 200 and sometimes 300 feet thick. The geology of the State hence is relatively simple. The chapter on building stones is the result of a careful study of the rocks, which included trials of strength besides ordinary and chemical analyses, the former by Professor J. A. Dodge, the latter by the same and his assistant Mr. C. F. Sidener. Four syenytes: 1. from Sherburne Co., 2. Beaver Bay Lake Co., 3, 4. Watab, Benton Co., afforded:

	SiO_2	AlO_3	FeO_3	MgO	CaO	K_2O	Na_2O	
1. Gray syenyte	65·12	16·96	4·69	1·99	4·77	2·18	3·07	= 98·78
2. Red syenyte	71·81	12·82	6·02	0·56	2·26	2·51	1·92	= 97·90
3. Whitish syenyte	62·06	19·29	4·67	3·06	5·93	1·62	2·45	= 99·68
4. Red syenyte	78·12	11·14	2·68	*tr.*	0·62	4·48	3·33	= 100·97

The chapters on the geology of the counties are illustrated by detailed maps. The noted locality of red pipestone of the "northwestern territory" is in Pipestone County, and a full history and description of it are given by Professor Winchell. The pipestone is a bed of indurated clay in the red quartzyte of the region.

7. *Tertiary Geology of the Eastern and Southern United States.*—Professor A. Heilprin's paper on this subject, noticed in volume xxiv of this Journal (1882), on page 228, is published in full in the Journal of the Academy of Natural Sciences of Philadelphia, Part I of vol. ix (1884).

8. *On the Development and Generic relations of the Corals of the Carboniferous System of Scotland;* by Mr. JAMES THOMSON, F.G.S. 208 pp. 8vo, with 14 plates. Read before the Philosophical Society of Glasgow, March 14th, 1883.—This memoir bears

evidence of being the result of much investigation. It discusses the relations of the various genera of Carboniferous corals and gives descriptions of many new species. A large number of species are figured on the plates, and many of the figures are from thin sections of the corals, illustrating growth and bud-development as well as distinctions in structure.

9. *Geologie von Bayern* (Bavaria), von Dr. K. W. von Gumbel. 1st part: Elements of Geology, and 1st "Lieferung," 208 pp., with numerous illustrations in the text. Kassel, 1884 (Theodor Fischer).—This volume is the first portion of an extended work on geology by Dr. von Gümbel, and includes an account of the constituents of rocks, and the methods of investigating them, descriptions of the constituent minerals, and then of the rocks themselves through part of the series. The cuts are illustrations of the optical characters of the minerals and rocks; and a large part of the rocks described are thus illustrated. The work promises to be an important contribution to geological science as well as a valuable text-book.

10. *Microscopic organisms in the Bowlder Clays of Chicago and vicinity;* by Messrs. Dr. H. A. Johnson and B. W. Thomas. (Bull. Chicago Acad. Sci., 1884.)—The authors of this paper report that the clay taken out from beneath Lake Michigan, in making the tunnel in 1865 to 1867 for supplying the city of Chicago with water, was found at that time to contain yellowish microscopic discs 1-85th to 1-250th of an inch in diameter. The facts were the occasion of the recent appointment of a committee by the Academy to make a general examination of the bowlder clays about Chicago; and the discoveries made by this committee are the subject of the recent communication. The clays contain fragments of shale, and from both the clay and the shale these discs were obtained. They are regarded as the macrospores of acrogenous plants, and similar to the *Sporangites bilobatus* or *Sp. Huronensis* of Dawson from Devonian shales. Along with the discs are "broken pieces of what seem to have been leaves." The clay underneath Chicago and its vicinity is full of bowlders, of various sizes up to several cubic yards, many with "ice-markings;" and some of the smaller are a carbonaceous shale which is apparently identical with that of the Upper Devonian; like that it burns with a bright clear flame giving out a strong petroleum odor.

Mr. Thomas, in a note appended to the article, states that he has detected the macrospores in the clay and in its imbedded fragments of shale along the west shore of Michigan from Kenosha, Wisconsin, to the Indiana line. In a "blue bowlder clay," from Litchfield, in Central Minnesota, he found an abundance of several species of fossil Rhizopods, fragments of Diatoms, and among the foraminifers, *Textilaria globosa*, *Rotalia globosa* and *Globigerina* (as identified by Dr. Joseph Leidy). The forms are marine and are supposed to come from Cretaceous beds. In a clay of the lower drift, from Bloomington, Illinois, at a depth

of 135 feet below the surface, occurs a stratum of black soil containing quantities of well preserved timber, with stumps of trees apparently in their natural position, and affording also discs like the macrospores of the Chicago clays, except that they are smaller.

11. *International Geological Congress.*—The meeting of the International Congress at Berlin has been deferred a year, in consequence of the cholera in Europe.

12. *Text-book of Descriptive Mineralogy ;* by HILARY BAUERMANN, F.G.S. 399 pp. 12mo. London, 1884 (Longmans, Green & Co.).—This volume is a companion to the *Treatise on Systematic Mineralogy* by the same author, published some three years since (this Journal, xxi, 506). The descriptions of species are brief, from the necessity of the case, but the matter is well selected and well arranged, so that the ordinary student will readily find almost all the information he needs. The work has many excellent features, not the least so being the figures printed from the original blocks used by Brooke and Miller, thirty years ago. It is not as fully up to date as it might be; thus we are told of cyanite that the "dimensions are undetermined;" no mention is made of vanadinite from Arizona, of danburite from Switzerland; and indeed it might be criticised in other minor points.

13. *On Herderite.*—Dr. A. WEISBACH has recently published a note in the Jahrbuch für Mineralogie (ii, 134, 1884) in which he gives the results of analyses by Winkler of the original herderite from Ehrenfriedersdorf and also of the allied mineral from Stoneham, Maine, first described by W. E. Hidden (this Journal, xxvii, 73, 135, 229). These analyses are quoted here, with also that made by J. B. Mackintosh upon the Stoneham mineral.

	1. Ehrenfriedersdorf. Winkler.	2. Stoneham. Winkler.	3. Stoneham. Mackintosh.
Phosphorus pentoxide	42·44	41·51	44·31
Beryllium oxide	8·61	14·84	15·76
Alumina	6·58	2·26	----
Iron sesquioxide	1·77	1·18	----
Lime	34·06	33·67	33·21
Water	[6·54]	6·59	loss 6·72
	100·00	100·05	100·00
			Fl 11·32

Analyses 1 and 2 were made upon $39{\cdot}5^{mm}$ and $101{\cdot}7^{mm}$ respectively. A comparison between analyses 2 and 3 shows that according to Winkler the Stoneham mineral contains some aluminum and iron together with the beryllium, and also that it contains water instead of fluorine—Winkler remarks upon a doubtful fluorine reaction, but is inclined to regard the loss as water. This loss, determined directly, he found to be 3·54 per cent at 350° and 7·59 at a red heat. Further it is seen that the original herderite differs from the Stoneham mineral in containing about half the beryllium replaced by aluminum and iron. The formula calculated from Winkler's results, if only beryllium is assumed

to be present, is $Ca_6Be_4P_6O_{27}+4H_2O$, which requires: phosphorus pentoxide 43·23, beryllium oxide 15·34, lime 34·13, water 7·30=100. Obviously, however, the material employed was too scanty to make the results thoroughly satisfactory. It is much to be desired that a new analysis of the Stoneham mineral may be made upon an amount of material sufficient to ensure accuracy, and thus its true composition be once for all established.

and collectors of antiquities. R.

14. *Deep-sea Fauna.*—In his address before the Biological Section of the British Association at Montreal, H. N. Moseley, Esq., President of that Section, and one of the Naturalists of the Challenger Expedition, states as a striking characteristic of the deep-sea fauna, the absence of Paleozoic types except among representatives of Mollusks and Brachiopods; of representatives of the Nautilidæ and Ammonitidæ; and of Lingulæ, these being, so far as has been discovered, shallow-water species. Mr. Moseley concludes that with little doubt the deep-sea fauna has been derived from the littoral and pelagic faunas. The fact that the young of littoral species are largely free-swimming and pelagic, and that pelagic species are often larval in form, favors the idea of their being ancestral; and he infers, thence, that by later modifications, the pelagic forms became adapted to the rougher littoral conditions; and from the littoral distribution later came the deep-sea life.

15. *Linnæan Society of New York*, vol. II.—This second volume of the N. Y. Linnæan Society contains two papers by Dr. C. H. Merriam, on the Vertebrates of the Adirondack Region (concluding the Mammalia), and a description of a new genus and species of the Sorecidæ, *Atophyrax Bendirii*. The latter is illustrated by a plate. The shrew was obtained by Captain Bendire about 18 miles southeast of Fort Klamath and a mile from Williamson's River. It is one of the largest of the Shrews.

16. George Bentham, *facile princeps* of Systematic Botanists in our day, died on the 10th of September, at his residence in London, at the ripe age of 84. An account of his life and scientific work may be expected in a future number of this Journal. A. G.

IV. Miscellaneous Scientific Intelligence.

1. *Annals of the Astronomical Observatory of Harvard College*, vol. xiv, Pt. I, 324 pp. *Observations with the Meridian Photometer during the years* 1879–82; by Edward C. Pickering, Director, aided by Arthur Searle and Oliver C. Wendell, Assistants in the Observatory. Cambridge, 1884.—This volume contains the results of photometric observations carried on at the Harvard Observatory between October 25, 1879 and September 17, 1882. The number of stars included is 4,260 being all those estimated to be of the first six magnitudes. The observations comprised 700 series and included 94,476 separate com-

parisons, or, including preliminary observations and those on stars not comprised in the catalogue, the total number exceeds one hundred thousand. These numbers are quoted as showing the magnitude of the work which has thus been successfully accomplished. The successive chapters in Part I, now published, contain a description of the photometer, a summary of series, a discussion of the effect of atmospheric absorption, results of direct eye estimates of relative brightness of the stars, the general catalogue, and some miscellaneous points connected with the work. The volume is accompanied by three plates.

2. *Dimensions of the Gulf of Mexico.* (Communication to Mr. J. E. Hilgard, Superintendent of the U. S. Coast and Geodetic Survey, by A. Lindenkohl, Assistant in the Coast Survey.—According to the calculation given in your "Basin of the Gulf of Mexico" (see this Journal, vol. xxi, April, 1881), the area of the Gulf of Mexico is 595,000 square miles and the area of the surface included within the 100-fathom line, 387,000 square miles; hence rather more than one-third of the surface of the Gulf (35 per cent) has a depth below 100 fathoms. The mean depth of the Gulf is 858 fathoms, which means that a basin of the same surface with the Gulf, and of the uniform depth of 858 fathoms will have the same capacity as the Gulf. Cutting off the banks, or those parts of the Gulf which are less than 100 fathoms deep, we obtain 1276 fathoms for the mean depth of the remainder. The figures 858 and 1276 are almost exactly in the ratio of two to three. The greatest recorded depth in the Gulf is 2119 fathoms, hence it will be seen that the mean depth is $\frac{2}{5}$ of the greatest and the mean depth of the deeper parts $\frac{3}{5}$ of the same.

3. *Bureau of Scientific Information. A generous gift of time and knowledge by members of the Academy of Natural Sciences of Philadelphia.*—With a view toward the more general dissemination of the results of scientific investigation, and of facilitating the work of the student in natural history, the following members and officers of the Academy of Natural Sciences have associated themselves into a Bureau of Scientific Information, whose function is to be the imparting, through correspondence, of precise and definite information bearing upon the different branches of the natural sciences. It is believed that through an organization of this kind considerable assistance can be rendered to those who, by the nature of their environs, are precluded from the advantages to be derived from museums and libraries.

The organization is of a purely voluntary character, and it is to be hoped that no unnecessary burden will be imposed upon its members by communications of an essentially trivial nature. The scope of the organization does not embrace considerations of a purely professional character—such as mineral or chemical analyses—nor the determination of collections, except by special agreement. The respondents may be addressed directly, care of the Bureau of Scientific Information, Academy of Natural Sciences. A return stamp (two cents) is all that is asked.

The bureau consists of the following persons: Joseph Leidy, M.D., Mycetozoa, Rhizopoda, Entozoa, Vertebrate Paleontology; Edward Potts, Pond Life, Fresh-water Sponges and Bryozoa; George W. Tryon, Jr., Conchology; Benjamin Sharp, M.D., Worms, Annelids, Histology; G. H. Horn, M.D., North American Coleoptera; H. C. McCook, D.D., Ants, Spiders, Insect Architecture; Henry Skinner, M.D., North American Moths; Eugene M. Aaron, Diurnal Lepidoptera; W. N. Lockington, Echinoderms, Fishes; Spencer Trotter, M.D., North American Ornithology; Thomas Meehan, Exotic and Cultivated Plants; J. H. Redfield, Ferns and North American Phanerogamic Plants; J. T. Rothrock, Vegetable Physiology; F. Lamson Scribner, Grasses; H. Carvill Lewis, Mineralogy, Glacial and Stratigraphical Geology; Angelo Heilprin, Invertebrate Paleontology, Physiography, Dynamical Geology; D. G. Brinton, M.D., Ethnology, American Linguistics and Archæology; Harrison Allen, M.D., Teratology; J. Gibbons Hunt, M.D., Microscopical Technology; E. J. Nolan, M.D., Bibliography of Natural History. Chairman, Professor Harrison Allen; Secretary, Professor Angelo Heilprin.

4. *Report upon the unification of Longitudes and a Universal time;* by BENJAMIN A. GOULD. Buenos Aires, July, 1884.—This report to the Minister of Public Instruction at Buenos Aires contains a brief discussion of the resolutions of the International Geodetic Conference, passed at their triennial session in Rome in October last. After stating his objections to the proposed method of numbering longitudes from west to east and the reason why the reversed order is to be preferred, Dr. Gould goes on to speak of the adoption of an international time.

"It is my belief that an accordance of all governments can be obtained in this matter of international time, with the same unanimity as in that of a common prime meridian, and I anticipate little difference of opinion upon the subject in the Washington Convention. The only probable discordance is relative to details in its application.

"An obstacle has nevertheless unexpectedly arisen in the United States, within the last few months, by the introduction, in many places, of a new system which I cannot but consider ill-judged and even mischievous; although it was designed to obviate the same difficulties which have prompted the suggestion of a universal time. The endeavor has been made, with considerable temporary success, to force into general use, in the interest of the railway companies, a system of time which is neither universal, local, nor scientific. Dividing the continent into sections by the meridians midway between those of 4^h, 5^h, 6^h, 7^h, and 8^h from Greenwich, it is attempted to introduce, throughout each of these sections, one and the same system of time for use both by the railroads and by citizens in their daily life. The time employed is that of Greenwich for the minutes and seconds, but using that hour which is nearest to the local mean time. . . . . The accordance of the public clocks, thus obtained for the various cities in

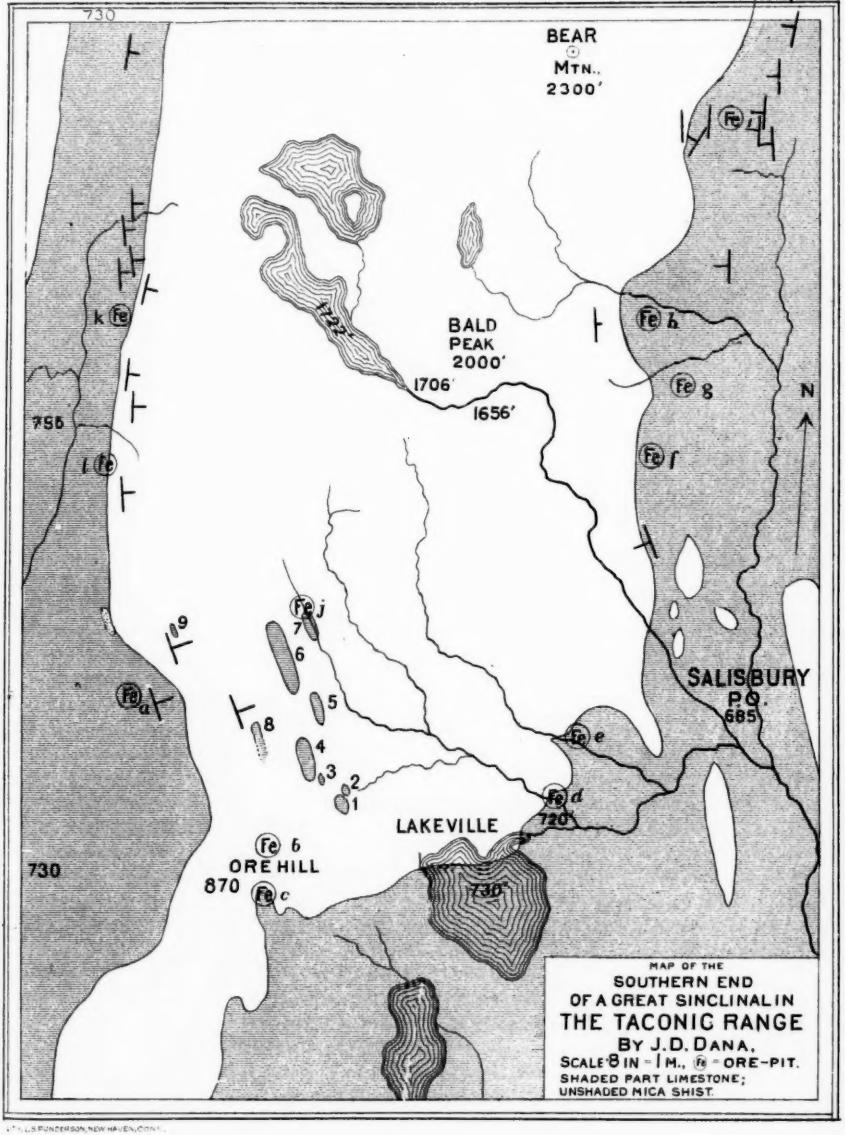
the same section, is a matter of some convenience for travelers and great advantage for the railroads; but it is secured by sacrifices which not only outweigh these advantages, but are in fact quite needless, since the desired end can be better attained by the total abandonment of any attempt to force an erroneous standard of time upon the community, and the adoption of the recommendation of the Geodetic conference.

"The facts of Nature demand a certain recognition; and the absurdity of the attempted change differs in degree only, not in kind, from that of a division of the year into a given number of equal lunations, or the month into a round number of equal days. The large deviation from the truth, in the standard of time thus imposed upon the inhabitants of regions near the boundaries of the proposed sections, can sometimes amount to three-quarters of an hour; and the moment to which the name of noon is thus given would divide the day into two unequal parts, whose inequality would, at certain seasons of the year, be very little less than an hour and a half. A man visiting his next door neighbor might find his watch to be an hour wrong. Such incongruities embarrass the affairs of daily life.

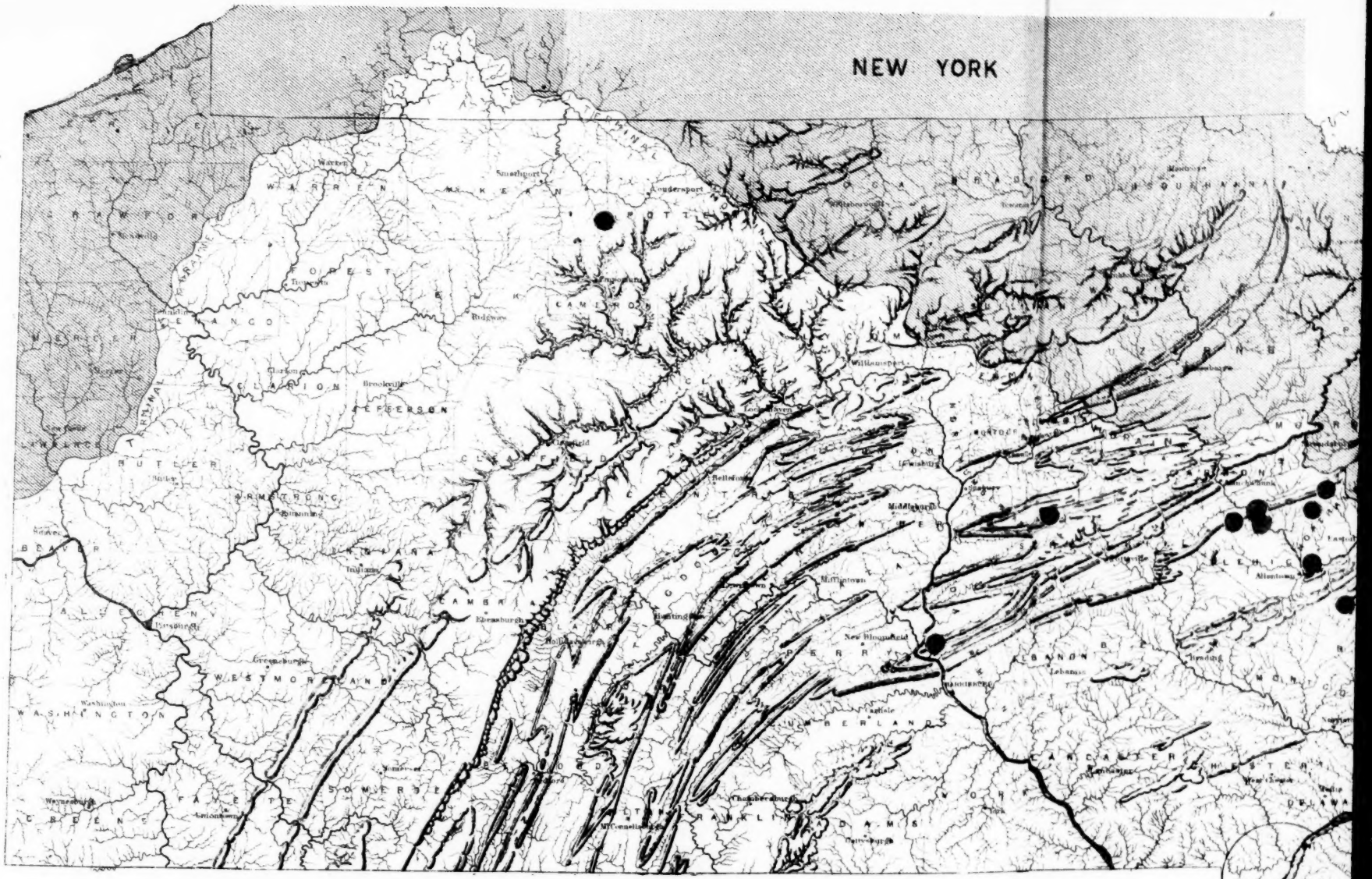
"Only some very strong necessity could justify such inconveniences and violations of natural laws; and no necessity exists. The only proper solution of the difficulty is by the establishment and maintenance of a distinct system of time, through the employment of a separate meridian for purposes other than local. This is now done by all navigators, all telegraph companies, and all railways of magnitude; and the reform now proposed by the International Geodetic Conference is simply that this separate meridian shall be the same for all, and in every part of the globe, and be likewise available for scientific purposes. The inconvenience of maintaining simultaneously two systems of time is reduced to a minimum when they are so different as to preclude all danger of confusion, when they are so easily convertible, and when one of them is identical for all the world. The method now proposed for attaining this end fulfils all these conditions; it entails less sacrifices than those required for the so-called 'standard time' of the North American railroads; and it cannot fail to afford practical, commercial and scientific advantages, while adding one more to the various bonds which are, of late years, uniting the nations of the earth in closer relations."

5. *The National Dispensatory*, containing the Natural History, Chemistry, Pharmacy, Actions and Uses of Medicines; by A. Stillé, M.D., LL.D. and J. M. Maisch, Pharm.D. 1,756 pp. Philadelphia, 1884 (H. C. Lea's Son & Co.).—A third edition of this standard work has been just issued, in which it has been thoroughly revised and much enlarged. The very large volume is handsomely printed and has many illustrations.

A final Report on the Crustacea of Minnesota, included in the orders Cladocera and Copepoda, together with a synopsis of the described species in North America and keys to the known species of the more important genera, by L. C. Herrick. 192 pp. 8vo, illustrated by 22 plates. From the 12th Ann. Rep. Geol. and Nat. Survey of Minnesota, Minneapolis, 1884.

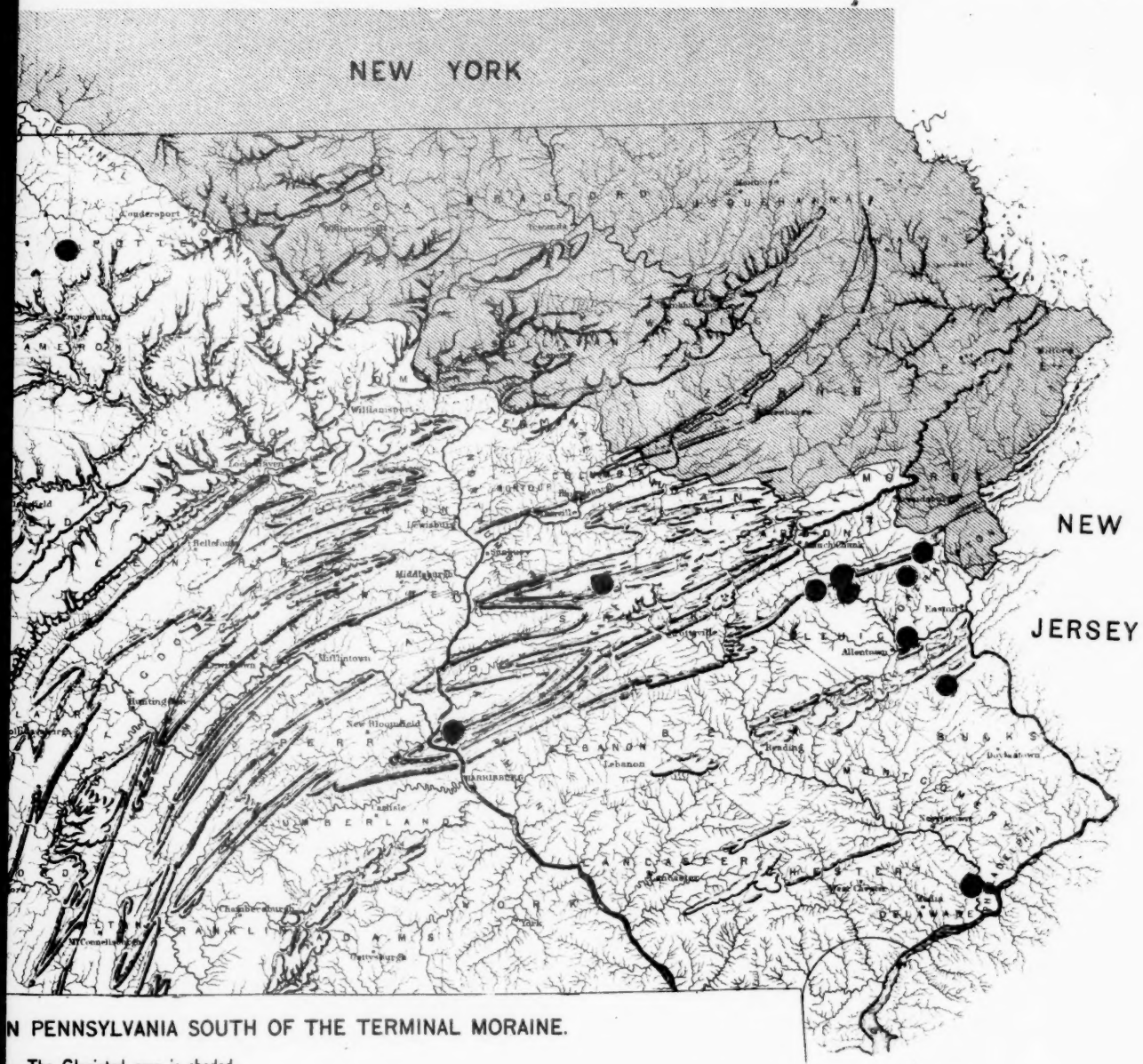


H.L.S. PUNDERSON, NEW HAVEN, CONN.



SUPPOSED GLACIATED LOCALITIES IN PENNSYLVANIA SOUTH OF THE TERMINAL MORAINE.

NOTE.—The Glaciated area is shaded.



N PENNSYLVANIA SOUTH OF THE TERMINAL MORAINE.

.—The Glaciated area is shaded.